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PALYNOLOGY OF DINOSAUR PROVINCIAL
PARK (CAMPANIAN) ALBERTA

by

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ABSTRACT

A well preserved and abundant palynoflora was recovered from sediment samples collected from Campanian age strata from Dinosaur Provincial Park. The described flora constitutes the first detailed investigation of the pollen and spores within the Park boundaries. Of the 85 identified taxa, the angiosperms are the most abundant and diverse and indicate a subtropical to tropical climate similar to present-day neotropical regions.

Numerical analysis of the palynomorphs does not reveal significant correlations and/or species groups across an east-west axis of the Park. In this respect the flora does not indicate floristic regions, geographical or stratigraphical variation which can be correlated with the vertebrate data presented by Béland and Russell (1978).

RESUME

Des échantillons de sédiments prélevés sur les couches campaniennes au Parc provincial des Dinosaures ont révélé une palynoflore abondante et bien préservée, dont la description constitue la première étude détaillée des pollens et spores qui se trouvent dans les limites du parc. Sur les quatre-vingt-cinq taxons identifiés, ceux des angiospermes -- les plus nombreux et les plus divers -- indiquent la présence d'un climat tropical et subtropical semblable à celui des régions néotropicales actuelles.

L'analyse numérique des palynomorphes ne révèle pas de corrélations notables et(ou) de groupes d'espèces suivant l'axe est-ouest du parc. En outre, la flore ne présente pas de subdivision régionale, ni de variation géographique ou stratigraphique qui pourraient se rapprocher des données de Béland et Russell (1978) sur les vertébrés.

INTRODUCTION

Dinosaur Provincial Park, located in southeastern Alberta, (Figure 1) is unique as a site of extensive badlands recognized as one of the worlds more important localities bearing late Cretaceous dinosaurian assemblages. Recently UNESCO has designated the Park as a World Heritage Site.

The Park covers an area of approximately 8,900 hectares and is deeply dissected by the Red Deer River and its tributaries (Figure 2). The landscape on first viewing appears stark, almost ominous to the untrained eye. Further, more detailed inspection however reveals a unique environment replete with its own mixture of prairie and badlands biota. The Park is alive with discrete, unassuming forms of life, inhabiting a part of the Earth in which the secrets of the geologic past are forever recorded.

The rock strata exposed, through the eroding action of the Red Deer River, rainfall and to a lesser extent wind, are primarily within a single lithostratigraphic unit, the Oldman Formation. These river sediments were deposited by meandering and braided streams about 75 million years ago (Campanian, Upper Cretaceous), and have yielded all of the fossil vertebrate remains so far collected from the Park (Jeletzky, 1971; Dodson, 1971; Russell, 1977).

Through the work of several paleontologists, much data have been collected concerning the sedimentology of quarry sites, the taxonomy and taphonomy of dinosaur remains, and the paleoecology of dinosaurian assemblages (Dodson, 1971; Dodson, 1975; Béland and Russell, 1978). Virtually nothing is known concerning the nature of the plants which existed during the time the Oldman Formation sediments were being deposited.

Paleobotanical investigations were traditionally centered around an examination of leaf and wood fossils. This approach was often hampered through a lack of abundant or well preserved material, and further through techniques which involved simple "leaf matching" with limited reference collections of extant leaf and wood specimens. Dilcher (1973) has remarked on the importance of careful morphological and anatomical studies necessary to correctly identify the megaf flora of Tertiary and older strata. Dilcher (1965, 1969), Dilcher and Mehrotra (1969) and Dilcher and Dolph (1970) have found that about 60% of the floras described by Berry (1916, 1930) from the Lower Eocene of southeastern North America are incorrectly identified. This alarming situation has led Dilcher and others to revise these floras using more sophisticated techniques involving foliar physiognomy, leaf margin

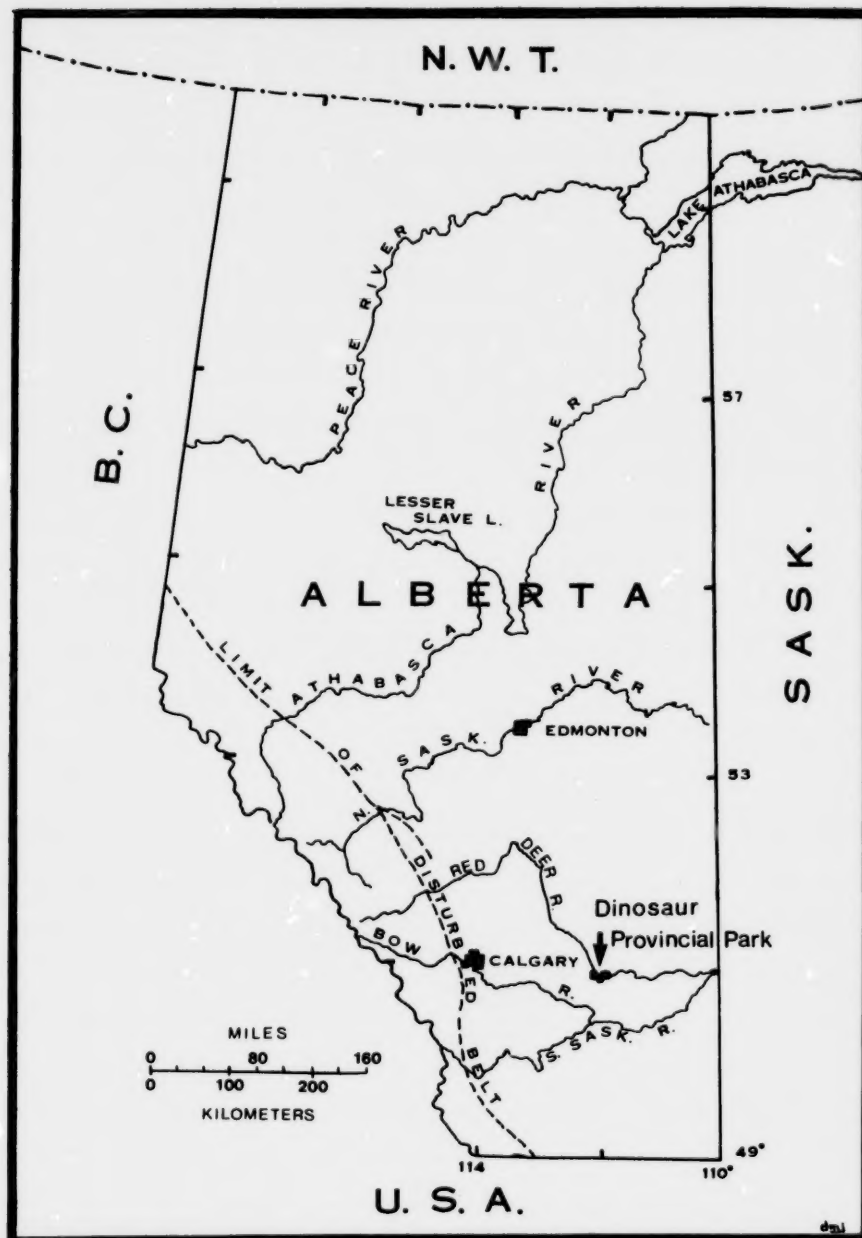


FIGURE 1. Map of Alberta showing the location of Dinosaur Provincial Park.

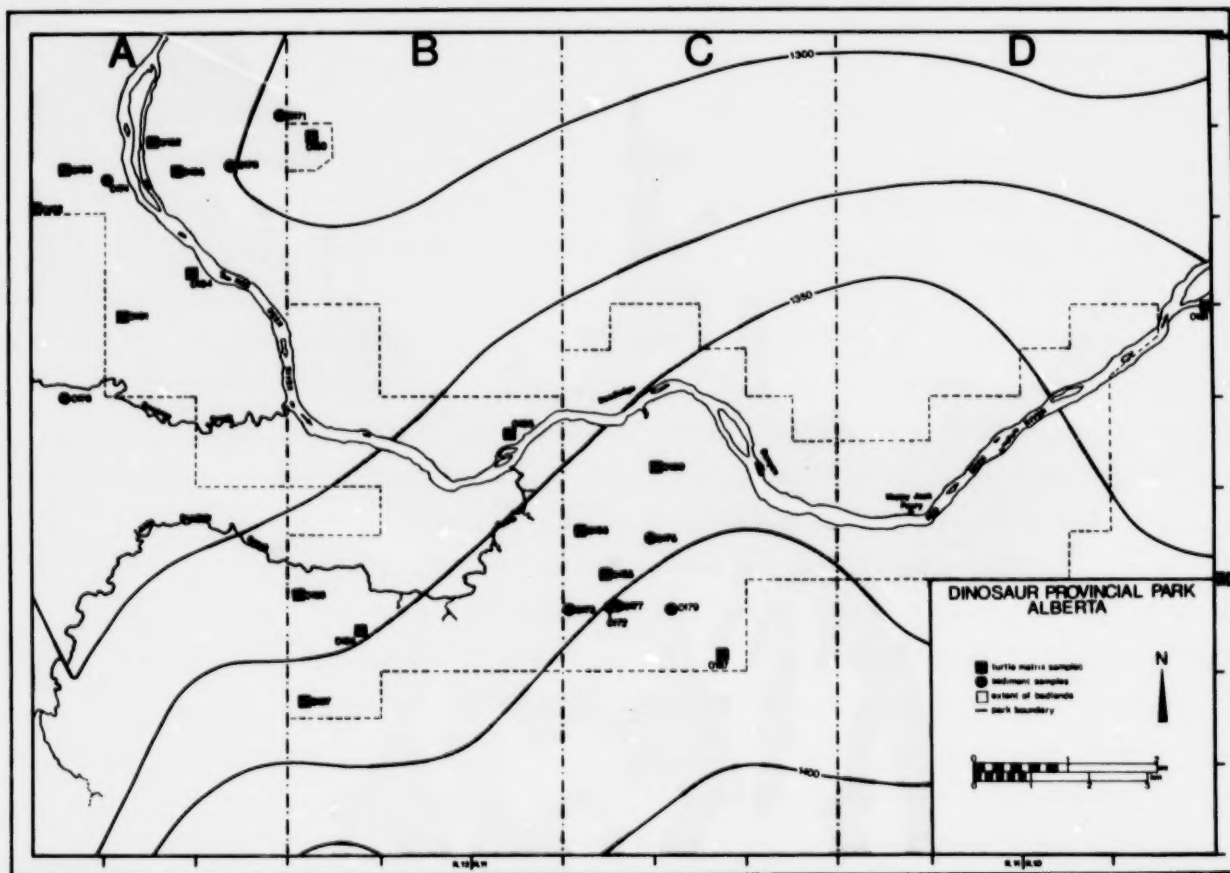


FIGURE 2. Map of Dinosaur Provincial Park showing location of turtle matrix and sediment samples. The badlands (stippled pattern) are divided into four areal subunits following the divisions of Béland and Russell (1978). Contours in 25 ft. intervals above sea-level are drawn on the subsurface configuration of the Pakowki-Milk River contact over the crest of the Sweetgrass Arch (Dodson, 1970).

analysis, leaf-size analysis, cuticular analysis and pollen analysis.

The study of fossilized pollen contained within the rock strata has several advantages over traditional plant megafossil studies.

Pollen and spores are produced by their parent plants in great numbers. Some forest trees as pines and spruce release so much pollen that the discharge is sometimes visible as an amber or yellow cloud over the forest. Swedish botanists have estimated that spruce forests of south and central Sweden produce 68,000 metric tons of pollen each year (Echlin, 1968). Coupled with this tremendous volume of pollen production is the fact that 80% to 90% of this pollen falls to the earth as the "pollen rain" into rivers, streams, lakes and bogs where it is incorporated into the sediment, destined to be fossilized.

The resistance of pollen and spores to atmospheric stress, and their resistance to post-depositional degradation has provided a nearly complete and abundant fossil record of the kinds of plants which have covered our Earth in the geologic past.

The morphological variation demonstrated by pollen is so great, that often a plant species can be identified solely by its pollen. Because of these factors of abundance, preservation and morphological variation; fossil pollen, once extracted from the rock sediments, can be used to describe the distribution, composition and structure of a fossil flora.

The purpose of this paper is threefold. The first objective is to record the occurrence of the fossil pollen and spores recovered from the Oldman Formation and to assign them when possible to published form-generic taxa. This will provide the first documentation of the palynomorphs (pollen and spores collectively) recovered from Dinosaur Provincial Park. The second objective is to compare the palynomorph distribution stratigraphically and areally with the known distribution of articulated remains of fossil vertebrates, as recorded by Béland and Russell (1978), to determine what significance, if any, exists between faunal and floral composition and distribution. The final objective involves a comparison of some of the fossil palynomorphs with extant palynomorphs in order to understand what kinds of plants are represented by the fossils.

With sufficient comparisons of this sort, certain conclusions can be made concerning the paleoenvironment and paleoecology of the Park during the mid-upper Campanian.

PREVIOUS WORK

Palynological studies of Upper Cretaceous deposits in Alberta and elsewhere within the western interior of North America are numerous (Snead, 1969; Srivastava, 1966-1972; Norton and Hall, 1969; Stanley, 1965; Leffingwell, 1971; Awai-Thorne, 1972; Jarzen, 1973 *et al.*) and have established a sequence of stratigraphically significant miospores useful in regional correlation of exposed and subsurface strata. Most of these studies however have not emphasized the use of miospores as indicators of paleoenvironmental conditions, and none of these studies have correlated the miospore data with information received from a study of large vertebrate communities.

Awai-Thorne (1972) has examined the palynofloral content of Campanian-Maestrichtian sediments from a 61 meter interval of the Canadian Pacific Oil and Gas (C.P.O.G.) Strathmore E.V. well located about 40 km. east of Calgary. The results of Awai-Thorne's (1972) work indicate a diverse and well preserved assemblage of pollen, spores, dinoflagellate cysts (marine phytoplankton) and megaspores. Paleoecological determinations, based on a comparison of miospore assemblages and megaspore and foraminifera from the Strathmore core (Wall *et al.*, 1971), indicate that the environment of deposition of the Oldman Formation was continental to deltaic.

Reference to the work of Awai-Thorne (1972) will be frequent throughout this paper since her study covers contemporaneous samples and geographically the closest comparison to the Dinosaur Provincial Park sediments.

Another study which will be useful in understanding the nature of the Park paleofloristics is that of Jarzen (1973). In this study Jarzen (1973) had a unique opportunity to examine the angiosperm sequence recovered from a continuously cored borehole in southcentral Alberta. The Amoco B-1 Youngstown Borehole spans a total section of 991 meters representing rock strata of Albian to Campanian age. The highest samples investigated by Jarzen (1973) are of the Middle Campanian Age (older than those of the Park) but provide a basis of comparison to determine the significance of some pollen and spores present in the DPP samples but not recovered by Awai-Thorne (1972).

Later Norris, Jarzen, and Awai-Thorne (1975) collaborated in an attempt to describe the sequence of terrestrial palynofloras present in sub-surface sections of Albian to Campanian marine and non-marine sediments in Southern Alberta. Previously studied Lower Cretaceous and Maestrichtian sections, and associated marine dinoflagellate cysts were used to date certain

evolutionary and migrational events within the terrestrial flora, and to establish a sequence of nine distinct floral suites which could be recognized elsewhere within the western interior of North America.

MATERIALS AND METHODS

Sample Collection:

Sixteen samples of sediment matrix were extracted from the NMNS collection of fossil turtle skeletons previously collected from Dinosaur Provincial Park. These samples are listed in Appendix 1 with relevant field and catalogue data. Additionally, 19 samples of outcrop sediments were collected by Dr. Dale Russell during his 1980 summer field season. The outcrop samples were collected from varied environments and from known quarry sites or sites of recent fossil vertebrate discoveries in order to have a sound and controlled basis for floral and faunal comparisons. A description of the lithology and location of the outcrop samples is presented in Appendix 2. The location of all samples are plotted on a base map of the Park in Figure 2. All samples were individually wrapped and sealed in polyethylene bags to avoid contamination between samples. Reference to all samples follows the numbering system established in the Palynological Laboratory (NMNS) which consists of a unique number (0191, 0192,...) applied to each separate locality within the park. Some outcrop samples were collected stratigraphically from a single locality and are designated 0179/1, 0179/2...0179/N.

Sample Preparation:

The turtle matrix and outcrop samples were processed using the standard hydrofluoric acid-oxidation-alkali method described by previous workers (e.g. Couper, 1958; Playford, 1962; Dettmann, 1963). The basic features of the process are as follows:

1. The crushed sample was digested in cold 48% hydrofluoric acid for 48 hours.
2. The by-product of this reaction was removed by several (3-10) washes in warm 25-50% hydrochloric acid.

3. Fine organic particles were dispersed and suspended by short centrifugation (1500 rpm for 45 seconds) using Darvan No. 4 (a mono-calcium salt of polymerized alkyl-aryl sulfonic acid, distributed by R.T. Vanderbilt Co., Inc., New York, New York).
4. The residue was then oxidized in concentrated nitric acid. If a second oxidation treatment was necessary this was done in Schulze's solution. Ten to 15 minutes oxidation was usually sufficient for most samples.
5. "Humic" material was removed with a 5% potassium carbonate or potassium hydroxide solution, followed by 3-5 washes in distilled water.
6. Heavy liquid separation using ZnBr_2 (sp. gr. 2.0) was necessary at this stage to reduce the amount of fine mineral matter.
7. Some samples with exceptionally coarse residues were sieved through a 20u mesh microsieve, following the procedure outlined by Kidson and Williams (1969).
8. Staining of samples in a 1% solution of Safranin-O was necessary at this stage.
9. The residue was strewn-mounted in 1% cellosize (W1188-A High Grade; Union Carbide Corp.) on Lucite (Elvacite 2044 Acrylic resin, E.I. DuPont de Nemours & Co., Inc.). The unused portions of the residues are stored in vials, with distilled water and phenol.

Location of Specimens:

Microscope slides are labeled with the printed label to the left of the observer. When placed on the microscope stage in this orientation (i.e. label to the left), specimens can be located by reference to stage coordinates. In the plate description, stage coordinates are given as horizontal followed by vertical. To facilitate conversion to other microscopes, England Slide Finder (ESF) designations are also provided. Another excellent method of converting microscope stage coordinates is described by Frederiksen (1978) and Cockbain (1980).

All slides, residues, and unused portions of samples are stored at the Palynology Laboratory, Paleobiology Division, National Museum of Natural Sciences, Ottawa, Ontario (K1A 0M8).

Photography:

Photographs were taken using either a Wild M-20 (100068) research microscope equipped with a Micro-Photoautomat Unit MKa5 or a Leitz Ortholux II (879887) equipped with a Leitz automatic camera. Kodak Pantaomic-X (16DIN) and Ilford Pan-F (18DIN) film were used to photograph the palynomorphs. Printing of specimens was done on Kodak Kodabromide F3 and F4 paper.

The plate of selected palynomorphs, the maps and tables were printed on Kodak Ektagraphic SC and Ilford Ilfospeed multigrade paper.

THE PALYNOFLORA

A total of 85 taxa of pollen and spores are identified from the Dinosaur Provincial Park samples. Of these taxa 33 (38.8%) represent the spores of ferns, hepatics and mosses; 12 (14.1%) represent the pollen of gymnosperms; 37 (43.5%) are the pollen of angiosperms; and the remaining 3 (3.6%) are of uncertain affinity. Of the angiosperms, species of *Aquilapollenites* account for 14.5% of the total flora and 32.4% of the angiosperm component.

The taxa are listed below in a taxonomic arrangement based on the morphology of the palynomorphs. The system is that of Potonié and Kremp (1954) with latter modifications by Potonié (1956, 1958, 1960, 1966) and Dettmann (1963).

Anteturma SPORITES

Turma TRILETES

Suprasubturma ACAVATITRILETES

Infraturma LAEVIGATI

Cyathidites australis Couper

Cyathidites minor Couper

Stereisporites antiquasporites (Wilson and Webster) Dettmann

Undulatisporites undulapolus Brenner

Infraturma APICULATI

- Acanthotriletes varispinosus* Pocock
- Acanthotriletes* spp.
- Heliosporites kemensis* (Chlonova) Srivastava
- Osmundacidites wellmanii* Couper
- Neoraistrickia truncatus* (Cookson) Potonié
- Baculatisporites comaumensis* (Cookson) Potonié
- Leptolepidites verrucatus* Couper
- Conv verrucosisporites* sp.
- Liburnisporites adnacus* Srivastava

Infraturma MURORNATI

- Retitriletes austroclavatidites* (Cookson) Potonié
- Retitriletes nidus* Srivastava
- Retitriletes* spp.
- Cicatricosisporites hallei* Delcourt and Sprumont
- Triletes bettianus* Srivastava
- Taurocusporites reduncus* (Bolikh.) Stover
- Taurocusporites segmentatus* Stover

Subturma ZONOTRILETES

Infraturma TRICASSATI

- Gleicheniidites senonicus* Ross
- Camarozonosporites insignis* Norris

Infraturma CINGULATI

- Cingutriletes clavus* (Balme) Dettmann
- Foraminisporis wonthaggensis* (Cookson and Dettmann) Dettmann
- Zlivisporis novamexicanum* (Anderson) Leffingwell

Turma MONOLETES

Suprasubturma ACAVATOMONOLETES

Subturma AZONOMONOLETES

Infraturma LAEVIGATOMONOLETI

- Laevigatosporites adiscordatus* Krutzsch
- Laevigatosporites discordatus* Pflug in Thomson and Pflug

Laevigatosporites druggii Srivastava

Laevigatosporites ovatus Wilson and Webster

Infraturma SULPTATOMONOLETI

Polypodiisporites amplus Srivastava

Turma HILATES

Aequitriradites spinulosus (Cookson and Dettmann)

Cookson and Dettmann)

Aequitriradites ornatus Upshaw

Anteturma POLLENITES

Turma SACCITES

Subturma Disaccites

Vitreisporites pallidus (Reissinger) Nilsson

Alisporites bilateralis Rouse

Alisporites spp.

Cedripites cretaceus Pocock

Parvisaccites radiatus Couper

Lygistepollenites sp.

Podocarpidites granulatus Singh

Podocarpidites spp.

Pityosporites sp.

Turma ALETES

Subturma AZONALETES

Infraturma PSILONAPITI

Taxodiaceapollenites hiatus (Potonié) Kremp

Turma PLICATES

Subturma POLYPLICATES

Equisetosporites multicostatus (Brenner) Norris

Subturma MONOCOLPATES

Cycadopites nitidus (Balme) Norris

Liliacidites mirus Srivastava

Liliacidites morrinensis Srivastava

Liliacidites varigatus Couper

Liliacidites spp.

Subturma TRIPTYCHES

Beaupreaidites angulatus (Samoilovitch) Srivastava
Beaupreaidites oculatus (Samoilovitch) Srivastava
Cercidiphyllites brevicolpatus Mchedlishvili
Cramwellia striata (Couper) Srivastava
Grewipollenites canadensis Srivastava
Loranthacites catterallii Srivastava
Retitricolpites vulgaris Pierce
Tricolpites parvistriatus Norton
Tricolpites reticulatus Cookson ex Couper
Tricolpites sagax Norris
Tricolpites striatus Couper

Subturma POLYPTYCHES

Penetetrapites mollis Hedlund and Norris

Subturma TRIPROJECTACITES

Aquilapollenites amplus Stanley
Aquilapollenites asper Mchedlishvili
Aquilapollenites attenuatus Funkhouser
Aquilapollenites calvus Tschudy and Leopold
Aquilapollenites clarireticulatus (Samoilovitch) Tschudy
Aquilapollenites pyriformis Norton
Aquilapollenites quadrilobus Rouse
Aquilapollenites reticulatus Stanley
Aquilapollenites trialatus Rouse
Aquilapollenites tripodiformis Tschudy and Leopold
Aquilapollenites turbidus Tschudy and Leopold
Aquilapollenites sp.

Subturma PTYCHOTRIPORINES

Infraturma OBLATI

Montanapollis endannulatus Tschudy
Fulcheripollenites narcissus Srivastava
Senipites drumhellerensis Srivastava
Symplocoipollenites vestibulum (Potonié) Potonié

Turma POROSES

Subturma TRIPORINES

Proteacidites thalmanii Anderson

Triatriopollenites costatus Norton

Triporopollenites rugatus Newman

Trudopollis meekeri Newman

Subturma POLYPORINES

Infraturma PERIPORITI

Erdtmanipollis procumbentiformis (Samoilovitch) Krutzsch

MIOspores INCERTAE SEDIS

Schizosporis parvus Cookson and Dettmann

Schizosporis sp.

Sigmopollis hispidus Hedlund

SUGGESTED BOTANICAL RELATIONSHIPS

The following classification of the fossil palynomorphs into extant families is based on direct comparison of the fossil pollen and spores with extant pollen and spores contained in the National Museum of Natural Sciences Palynology Reference Collection. The collection, numbering 9,000 species is oriented towards tropical and subtropical species, but is representative of a world-wide flora. The taxonomic arrangement of major plant divisions is after Bold *et al.* (1980), family names follow Airy Shaw, (1973).

The placement of some fossil palynomorphs into extant taxa are more secure than others, but at the family level, it is felt that the assignments are logical and conservative.

BRYOPHYTA

Family Sphagnaceae

Cingutritetes clavus

Stereisporites antiquasporites

ANTHOCEROTOPHYTA

Family Anthocerotaceae

Foraminisporis wonthaggensis

HEPATOPHYTA

Family Sphaerocarpaceae

Aequitriradites oranatus

A. spinulosus

MICROPHYLLOPHYTA

Lycopodiales

Family Lycopodiaceae

Retitriletes austroclavatidites

R. nidus

Selaginellales

Family Selaginellaceae

Acanthotriletes varispinosus

Heliosporites kemensis

Neoraistrickia truncatus

PTERIDOPHYTA

Filicales

Family Osmundaceae

Baculatisporites comamensis

Osmundacidites wellmanii

Family Schizaeaceae

Cicatricosisporites halleti

Family Gleicheniaceae

Gleicheniidites senonicus

Family Polypodiaceae

Laevigatosporites adiscordatus

L. discordatus

L. druggii

L. ovatus

Polypodiisporites amplus

Family Cyatheaceae/Dicksoniaceae

Cyathidites australis

C. minor

CYCADOPHYTA

Cycadales

Cycadophytus nitidus

Pteridospermales

Family Caytoniaceae (extinct)

Vitreisporites pallidus

CONIFEROPHYTA

Conferales

Family Pinaceae

Alisporites bilateralis

Cedripites cretaceus

Pityosporites sp.

Family Podocarpaceae

Parvisaccites radiatus

Podocarpidites granulatus

Family Phyllocladaceae

Lygistepollenites sp.

Family Taxodiaceae/Cupressaceae

Taxodiaceapollenites hiatus

GNETOPHYTA

Family Ephedraceae

Equisetosporites multicostratus

ANTHOPHYTA

Family Buxaceae

Erdtmanipollis procumbentiformis

Family Cercidiphyllaceae

Cercidiphyllites brevicolpatus

Family Gunneraceae

Tricolpites reticulatus

Family Liliaceae

Liliacidites mirus

L. morrinensis

L. variegatus

Family Loranthaceae/Santalaceae

Aquilapollenites amplius

A. asper

A. attenuatus

A. calvus

A. clarireticulatus

A. pyriformis

A. quadrilobus

A. reticulatus

A. trialatus

A. tripodiformis

A. turbidus

Cranwellia striata

Loranthacites catteralli

Family Proteaceae

Beaupreaidites angulatus

B. oculatus

Proteacidites thalmanii

Family Symplocaceae

Symplocoipollenites vestibulum

Family ? Anacardiaceae

Pulcheripollenites narcissus

The plant families with which the fossil pollen and spores share affinities are discussed below. The arrangement is taxonomic, and much data are taken directly from Airy Shaw (1973), Bold *et al.* (1980), Graham and Jarzen (1969), and Jarzen (1973).

The Division Bryophyta (the mosses) are a group of non-vascular terrestrial plants, with over 25,000 identified species. The family Sphagnaceae, the largest within the group are typically low lying spongy, pale green mats common in low wet or damp places, especially where soil is not markedly alkaline. *Sphagnum* the single genus within the family commonly inhabits the shores of ponds and lakes. Fossil spores of *Sphagnum* are known from the Jurassic period (Balme, 1957).

The fossil spores, *Cingultriletes clavus* and *Sterisporites antiquasporites*, unmistakably share affinity with extant spores of *Sphagnum*.

The Family Anthocerotaceae comprises four genera with an unknown number of species in each genus (Proskauer, 1948). The group are land plants with a lobed thallose body which undergoes an alternation of generations.

Jarzen (1979) has discussed the fossil occurrences of Anthocerotaceae spores in the Cretaceous of North America and concluded that often extreme morphological variation exists among the spores of a single extant plant, and this condition probably also occurs in the fossil species. The fossil spore form *Foraminisporis wonthaggensis* shares affinity with extant Anthocerotaceae.

The plant division Hepatophyta or liverworts contain about 300 genera and between 8,000 and 10,000 species, and are among the most primitive extant land plants. Fossil hepatics are known from the Silurian period (Savicz-Ljubitzkaja and Abramov, 1959). Several of the genera are aquatics, but most are restricted to moist terrestrial habitats. The two species of *Aequitriradites* recovered from the Dinosaur Provincial Park samples are very comparable to some extant hepatic spores of the family Sphaerocarpaceae (Dettmann, 1963).

The Lycopodiaceae comprise two genera (*Lycopodium* and *Phylloglossum*) with about 450 species of tropical and temperate, mostly saprophytic, low, evergreen plants. The spores of temperate forms, and those most frequently recovered from Mesozoic and Cenozoic deposits in the northern hemisphere are characterized by a distinct reticulum on the distal surface. The pollen species *Retitriletes austroclavatoides* and *R. nidus* almost certainly represent lycopodiaceous plants.

The family Selaginellaceae is monogeneric with over 700 species of chiefly tropical distribution. The genus *Selaginella* is closely related to the lycopods but differs from these plants in that *Selaginella* produces two kinds of spores, a condition known as heterospory. The smaller spores, the microspores, are comparable to the fossil species *Acanthotriletes varispinosus*, *Heliosporites kemensis*, and *Neoraistrickia truncata*. The genus is common in damp places, especially forests. *Selaginella* are small, leafy often mat forming plants of evergreen habit.

The fern family Osmundaceae comprises three genera (*Leptopteris*, *Osmunda* and *Todea*) and 19 species of tropical to temperate cosmopolitan distribution. Of the three genera, the spores of *Osmunda* based on size, and details of surface sculpture are most similar to the spores of the fossil taxa *Baculatisporites* and *Osmundacidites*. Spores of extant *Osmunda* display a variety of surface ornament from coarsely granulate to distinctly bacculate.

The mostly tropical fern family Schizaeaceae, with only four genera but over 150 species does contain a few subtropical and temperate representatives (e.g. *Schizaea pusilla* occurs in Canada in Newfoundland and Nova Scotia). The spores of all genera were examined and only *Mohria* approaches the cicatricose sculpture so distinctive of *Cicatricosisporites hallei*. The sculpture elements of *Anemia* are often elevated, blunt tipped spines, while *Lygodium* characteristically is verrucate or irregularly crossed with broad rugulae. The spores of *Schizaea* are rarely trilete. *Mohria* has three species of tropical and South African distribution.

The family Gleicheniaceae comprises four genera and over 150 species of tropical, subtropical, and southern temperate, often thickets forming "sunferns". The spores of *Gleichenia* are most often bilateral and monolete, however *G. circinata* is radiosymmetrical with a trilete scar (for discussion of the spore types in *Gleichenia* see Selling, 1946; and Harris, 1955; and for those in *G. senonicus* Ross see Skarby, 1964). The characteristic tori (narrow band-like thickenings of the spore wall, more or less parallel to the laesurae; [see Kremp, 1965]), are well developed on *G. circinata*. The fossil spore *Gleicheniidites senonicus* has weaker, less developed tori and in this respect more closely resembles *Hicriopteris* (*Dicranopteris*) *glauca*. Copeland (1947) states that the family Gleicheniaceae is recorded in the fossil record from the Jurassic, and probably occurs in even older strata.

The Polypodiaceae are an enormously large family of ferns with over 50 genera and an uncertain number of species—perhaps 300–400 species would be conservative. The spore morphology of the 30 species examined is extremely stenopalynous and does not allow separation of the fossil forms of *Laevigatosporites* into generic groups. Recently Phadtare and Kulkarni (1980) extracted the spores of *Laevigatosporites ovalis* from sporangia having affinity with the Polypodiaceae, from Tertiary lignites in India. The plants represented by the fossil spores at best can only be compared at the family level. The Polypodiaceae today, are almost exclusively epiphytes of very wet tropics throughout the world.

Two of the tree fern families, the Cyatheaceae and Dicksoniaceae are probably represented in the Dinosaur Provincial Park palynoflora judging from the frequent occurrence of *Cyathidites australis* and *C. minor*. Two genera, *Cyathea* and *Cnemidaria*, are included in the Cyatheaceae, and together comprise over 600 species of mostly large, arborescent tree ferns of the tropics and subtropics. The Dicksoniaceae have been variously

united with Cyatheaceae or more recently separated to include five genera. The habit and distribution of the Dicksoniaceae parallels that of the Cyatheaceae.

Cyathea is a tropical and subtropical genus of approximately 600 species. It is a characteristic aborescent fern (some species attain heights of 25m.) of the wet tropics, especially in tropical mountains. Species of the genus are common secondary invaders of impoverished soils in damp climates, especially at low altitudes (Richards, 1966).

Cycadophytus nitidus is in all probability an extinct member of a unique group of gymnospermous plants, the Cycadales. The cycads of today are the survivors of a much larger group of plants which in the geologic past (especially at the end of the Triassic and into the Jurassic) were a much more conspicuous part of the terrestrial flora. The order today contains three families (Cycadaceae, Stangeriaceae and Zamiaceae) whose distribution includes the Malagasy Republic, Eastern Asia, Indomalaysia, South Africa and warm temperate to tropical parts of Australia, the Americas, and Africa.

The family Caytoniaceae is an extinct group of gymnospermous plants common during middle Jurassic times. The pollen grains of *Vitreisporites pallidus* are identical to the pollen associated with the fossil microsporophyll *Caytonanthus* (Couper, 1958; Harris, 1937).

The Pinaceae are the largest family of conifers, with a distribution throughout the northern hemisphere, and southward to Sumatra, Java, Central America, and West Indies. The plants are usually trees, but rarely prostrate or creeping shrubs. Most of the 10 genera bear pollen with air bladders (bisaccate) except *Tsuga*, *Pseudotsuga* and *Larix*. It is difficult or impossible to compare fossil bisaccate pinaceous pollen directly with an extant genus. The detailed light microscopy and scanning electron microscopy studies necessary to ascertain affinities of these pollen forms is beyond the scope of this paper. The following taxa however can safely be placed in the Pinaceae: *Alisporites bilateralis*, *Alisporites* sp., *Cedripites cretaceus* and *Pitysporites* sp.

The Podocarpaceae are primarily a southern hemisphere family of conifers, but range northward to Japan, Central America and the West Indies. The six genera and 125 species are trees or shrubs. The genus *Podocarpus* is the largest with over 100 species occurring in southern hemisphere tropical and subtropical environments, with a few exceptions extending north to the Himalayas and Japan. In the Americas, 16 species of *Podocarpus* occur in Mexico, Central America and the Antilles (Graham and Jarzen, 1969). The genus is a characteristic representative of montane tropical forests, although more abundant near the bottom of slopes in moister soils (Gleason and Cook, 1926). It is a medium-sized tree (10m.)

and produces pollen nearly throughout the year (Little and Wadsworth, 1964). Couper (1953) has provided an account of the Cretaceous and Tertiary occurrence of Podocarpaceae in the southern hemisphere.

The Phyllocladaceae (morphologically and anatomically very similar to the Podocarpaceae) are a small family of conifers with a single genus - *Phyllocladus*. The genus of seven species occurs today in the Philippine Islands, Borneo, Moluccas, New Guinea, Tasmania and New Zealand. Its distribution during the Mesozoic was confined to south-eastern Australia, Tasmania, New Zealand and southern most South America (Keng, 1978; Couper, 1960). The small, often deflated air bladders which do not extend much beyond the equatorial diameter of the body of the grain, and the lack of proximal tubercles, are features which characterize the fossil genus *Lygistepollenites* (Stover and Evans, 1973; Playford and Dettmann, 1978).

The Taxodiaceae are a family of 10 genera and 16 species of gymnosperm medium-sized to giant trees. Their distribution includes Eastern Asia, Tasmania and North America. The Cupressaceae are another gymnosperm family of trees or shrubs with 19 genera and about 130 species. The Cupressaceae are cosmopolitan in their distribution. The pollen species *Taxodiaceapollenites hiatus* can best be compared to both families.

The family Ephedraceae is a family of gymnosperms comprised of the sole genus *Ephedra* with about 40 species. The genus *Ephedra* are xerophytic seed-bearing plants which differ from other gymnosperms in a number of important features, primarily in having vessels in the secondary xylem. The plants are much branched shrubs with leaves reduced to scales. The genus occurs today in northern and southern hemisphere warm temperate environments.

The fossil genus *Equisetosporites* is reserved for polyplicate pollen with smooth rounded ridges which coalesce at the longitudinal ends (Srivastava, 1968a).

The Buxaceae are a dicotyledonous family of four genera and 100 species of evergreen shrubs, rarely trees or herbs.

The pollen of *Pachysandra* Michx. and *Sarcococca* Lindl. are nearly identical to each other and the group can be compared favourably with the fossil taxon *Erdtmanipollis procumbentiformis* (Samoilovitch) Krutzsch. Gray and Shoma (1964) have demonstrated that frequently (but not consistently) the pore number of the pollen grains can be used to distinguish the extant species of *Pachysandra* and *Sarcococca*. *Pachysandra* occurs in North America in rich calcareous woods from Kentucky southward to western Florida and Louisiana (Fernald, 1950). In Japan, *Pachysandra* is found growing in the herb layer of

rich mesophytic forests of volcanic mountains. Associated trees of these forests include species of *Alnus*, *Betula*, *Acer*, *Cornus*, *Populus* and *Salix* (Numata, 1974).

Very little is known about the ecology of *Sarcococca*, but Standley and Steyermark (1949) have reported the genus from southern Mexico and Central America in open oak woods and moist *Cupressus* forests at elevations of 2190 to 2460 meters.

The largest concentration of both genera is in central China and the southeastern United States. The region in central China is noted floristically for its large proportion of relict genera and endemic species (Gray and Shoma, 1964).

The Cercidiphyllaceae is a monogeneric family of dictotyledons occurring today only in China and Japan. The genus *Cercidiphyllum* comprises two species of dioecious, deciduous trees. The pollen is probably airborne, based on the smooth exine surface. The fossil pollen form *Cercidiphyllites brevicolpatus* superficially resembles the pollen of extant *Cercidiphyllum*.

Fossil pollen comparable to the Cercidiphyllaceae are known from the Cretaceous of the U.S.S.R. (Samoilovitch and Mchedlishvili, 1961) and Canada (Jarzen, 1973; 1978).

The south temperate family Gunneraceae with its sole genus *Gunnera* comprises about 50 species of perennial, rhizomatous herbs with radical, long-petioled ovate or obicular leaves which in some species attain enormous dimensions (Palkovic, 1974). The species occurs in Africa (Kenya, Tanzania and South Africa) the Malagasy Republic, Malaysia (except the Malay Peninsula), Solomon Islands, Tasmania, New Zealand, Hawaii, the islands of Juan Fernandez and from Veracruz, Mexico southward to Chile and Argentina. The species are typical of environments with moderate to heavy rainfall and moderate to high elevation (Hope, 1976; Palkovic, 1974).

Jarzen (1980) demonstrated the long history of *Gunnera* from the Upper Cretaceous to the present. In the Maestrichtian within the western interior of North America, *Gunnera* was one of the more common taxa whose range has been progressively reduced since the close of the Cretaceous. The infrequently occurring fossil pollen *Tricolpites reticulatus* represents the extant genus *Gunnera* in the Dinosaur Provincial Park samples.

The monocotyledonous family, Liliaceae, with over 250 genera and 3700 species of mostly herbaceous habit, is cosmopolitan in distribution filling nearly all types of habitats. The Liliaceae are linked with the Amaryllidaceae through the Alliaceae. The size of the family, and stenopalynous nature of the pollen (Erdtman, 1972) does not allow a generic comparison

with the fossil pollen species of *Liliacidites* recovered from the Dinosaur Provincial Park samples.

The Loranthaceae are a dicotyledonous family of parasites comprising 36 genera and more than 1500 species of tropical and temperate distribution. Most are small semi-parasitic shrubs which attach to their hosts by haustoria (Kuijt, 1969). Jarzen (1977) suggested that the fossil pollen genus *Aquilapollenites* represents two lines of development from a Santalalean stock. The isopolar forms of *Aquilapollenites*, which include *A. amplus*, *A. asper*, *A. attenuatus*, *A. claireticulatus*, *A. quadrilobus*, *A. reticulatus*, *A. trialatus* and *A. turbidus* bear a close morphological and probably genetic relationship with the extant plant family Loranthaceae. The heteropolar species of *Aquilapollenites* including *A. calvus*, *A. pyriformis* and *A. tripodiformis* recovered from Dinosaur Provincial Park share affinity with the extant Santalaceae.

The fossil taxa *Loranthacites catterallii* and *Cranwellia striata* bear close morphological features with the pollen of certain genera of the Loranthaceae. Srivastava (1966) established *Cranwellia* to include fossil pollen grains which bear an affinity with the pollen of the extant genus *Elytranthe* (Loranthaceae). Mildenhall (1978), based on a re-examination of type material of fossil *Elytranthe* pollen suggested that *Cranwellia striata* (Couper) Srivastava recovered from North American and Russian sediments do not compare very well with the pollen of extant *Elytranthe*.

Until further, more detailed examinations can be made, *Cranwellia striata* recovered from the Dinosaur Provincial Park samples is best compared at a family level to the Loranthaceae.

The Proteaceae are one of the largest families among the dicotyledons with 62 genera and over 1,050 species. They are distributed throughout tropical regions of the southern hemisphere. The flowers are often very large, colourful or showy, and have their pollen freely exposed. The exposed pollen is borne from protandrous flowers and pollination is by birds and insects.

The Symplocaceae are a family of two genera and about 500 species. The family comprises shrubs and trees of tropical and subtropical distribution (especially in Africa). The larger genus *Symplocos* with 350 species occurs today in tropical and subtropical environments of Asia, Australia, Polynesia and the Americas.

The Anacardiaceae are a dicotyledonous family of trees and shrubs comprising 60 genera and 600 species of chiefly tropical distribution. The family also has representatives in the

Mediterranean region, eastern Asia and America. Pollination within the Anacardiaceae is by vectors other than wind.

COMPARISONS WITH OTHER UPPER CRETACEOUS PALYNOFLORAS

Waldman and Hopkins (1970) recovered a diverse assemblage of spores and pollen from 5 coprolite samples from the Oldman Formation of Alberta. Of the 15 genera recorded by Waldman and Hopkins, species of five of these occur within the Dinosaur Provincial Park samples (*Lycopodiumsporites/Retitriletes*, *Gleicheniidites*, *Laevigatosporites*; *Liliacidites*, and *Aquilapollenites*.)

Newman (1964) described and correlated the palynologic composition of three outcrop sections of late Cretaceous and Paleocene age from the Sand Wash and Piceance Basins in Northwestern, Colorado. Eighteen (46%) of the 329 genera identified by Newman occur in the Dinosaur Provincial Park samples. Of special note is the occurrence of *Trudopollis meekeri* Newman in both the Dinosaur Provincial Park samples and the material from Colorado. Although *Trudopollis* is a form genus of a morphological group of extinct and uncertain affinities of angiosperm pollen characteristic of the eastern North American and European Upper Cretaceous province, its presence in the western interior is frequent enough to be used to characterize middle Campanian age sediments (Jarzen and Norris, 1975; Newman, 1965; Tschudy, 1980).

Brideaux (1971) examined the palynomorph content (miospores and dinoflagellate cysts) of four sections of the type locality of the Little Bear Formation southwest of Fort Norman, District of Mackenzie. Based on the restricted ranges of several taxa (including species of *Aquilapollenites*) and the absence of others (e.g. *Wodehouseia*), Brideaux proposed a Campanian or possibly Early Maestrichtian age for the Little Bear and basal portion of the East Fork Formation. The Dinosaur Provincial Park palynoflora shares a 60% similar composition with Brideaux's East Fork flora and a 53% similarity with his Little Bear flora. This strong correlation supports Brideaux's proposal of a Campanian age for his sections.

A small, but stratigraphically significant, assemblage of pollen and megaspores assisted Wall and Singh (1975) in assigning a Campanian age to an outcrop section of an unnamed shale unit in the Buffalo Head Hills of north-central Alberta. Pollen recovered by Wall and Singh which is also present in the Dinosaur Provincial Park samples includes *Aquilapollenites trialatus* Rouse, and *A. turbidus* Tschudy and Leopold. Both species are very

characteristic of (the former probably restricted to) the Campanian in the western interior (Rouse, 1957; Tschudy and Leopold, 1971; Awai-Thorne, 1972).

Jarzen (1973) identified 47 species of angiosperm pollen from the Campanian Foremost Formation of the Amoco B-1 Youngstown borehole in southern Alberta. Of these 47 species, 20 (42.5%) also occur in the Dinosaur Provincial Park samples. Jarzen (1973) recorded 11 species of *Aquilapollenites* from the Foremost Formation, of which 6 (54.5%) occur in the Dinosaur Provincial Park samples.

The most marked comparison of the palynoflora recovered from the Dinosaur Provincial Park samples is with that of the C.P.O.G. Strathmore EV well in southern Alberta (Awai-Thorne, 1972). Awai-Thorne (1972) recovered 55 species of miospores from the Oldman Formation samples of cored material. A graphic comparison of the composition of the Strathmore and Dinosaur Provincial Park assemblages is given below:

STRATHMORE WELL		%	D.P.P. SAMPLES		%
A.	Spores ¹	21	(38.2)	33	(38.8)
B.	Gymnosperm pollen	9	(16.3)	12	(14.1)
C.	Angiosperm pollen	25	(45.5)	37	(43.5)
D.	OTHERS ²			3	(3.6)
TOTAL SPECIES		55		85	

Within each category or major group (A,B,C,) the following comparisons are noteworthy. Of the 21 spore species identified by Awai-Thorne, 13 (62%) are also in the Dinosaur Provincial Park samples; of the 9 gymnosperm species 7 (78%) are present in the Dinosaur Provincial Park samples. Thirteen (52%) of the angiosperm pollen species recovered by Awai-Thorne were identified from the Dinosaur Provincial Park samples.

In the present study, 11 species of *Aquilapollenites* were identified (several additional forms were noted but remain unidentified) while Awai-Thorne (1977) identified 15 species of *Aquilapollenites*. Common species to both sections include *Aquilapollenites quadrilobus*, *A. amplus*, *A. attenuatus*, *A. calvus*, *A. clarireticulatus*, *A. trialatus* and *A. turbidus* and represent a correlation of 46.6%.

Norris, Jarzen and Awai-Thorne (1975) defined a sequence of terrestrial palynofloras

1. includes, ferns, hepatics, liverworts, and mosses.
2. incertae sedis

into nine distinct suites as occurring in subsurface sections of Albian to Campanian marine and non-marine sediments in southern Alberta. Eight of these suites were recognized from the Amoco B-1 Youngstown borehole (L.s.d. 6-34-30-8W4; lat. 51° 37'N, long. 111° 2'W) and were used to characterize the following stages of the Upper Cretaceous. The earliest suite, the Pre-Tricolpate defined the Middle Albian; younger suites include Early Tricolpate (Upper Albian to ? Cenomanian at top); Nyssapollenites (Cenomanian); Early Triporate (Turonian to ? Lower Senonian); Early Lorantheaceous (? Santonian to Lower Campanian); Later Lorantheaceous (Lower to Middle Campanian); The Advanced Angiosperm suite characterized the lower part of the Middle Campanian and the Trudopollis suite defined the latter Middle Campanian (Upper Campanian not present in the Youngstown well).

Within the C.P.O.G. Strathmore EV well (L.s.d. 7-12-25-25 W4; lat. 51°7'N, long. 113° 20'W) two suites were recognized and include the Trudopollis suite (mid-Campanian) and the Granwellia suite (Upper part of the Upper Campanian). The Trudopollis suite is characterized by the common and often dominant occurrence of the gymnosperms *Taxodiaceapollenites hiatus* and *Sequoiapollenites paleocenicus*, the pteridophytes *Gleichenioidites senonicus*, *Laevigatosporites ovatus* and *Umbosporites callosus* and the angiosperms *Betulaceoipollenites* sp., *Aquilapollenites trialatus*, *A. quardilobus* and *Tricolpites reticulatus*. Other taxa which occur as members of the Trudopollis suite in the Youngstown and Strathmore wells are *Aquilapollenites calvus*, *A. turbidus*, *Fulcheripollenites krempii*, *Symplocoipollenites* sp., *Liliacidites mirus*, *Zliviisporis* sp., cf. *Z. novamexicanum*, and the ubiquitous *Cyathidites minor* and *C. australis*. *Trudopollis meekeri* occurs in this suite.

The close similarity between the palynoflora recovered from Dinosaur Provincial Park and the Trudopollis suite as defined by Norris *et al.* (1975) supports a mid-upper Campanian age for the Dinosaur Provincial Park sediments.

QUANTITATIVE DATA AND INTERPRETATION

Counts of 300 palynomorphs were made for all samples except samples 0181, 0185, 0194, 0175, 0176, 0197/1 and 0179/5 in which the concentration was so poor as to render the samples "barren".

The contained palynomorphs were calculated as percentages (Tables 1,2) which represent the relative abundance of each taxon. When a particular taxon is known to occur within a

TURTLE MATRIX	TAXON	S	A					B					C					D
			0182	0188	0191	0192	0196	0194	0183	0197	0199	0184	0185	0196	0186	0189	0187	
	<i>Cystodites australis</i>		3	8	3	3	8	17	10	3			7	3	3	22		
	<i>Cystodites minor</i>		24	35	25	10	24	37	23	10	27		38	31	3			
	<i>Sternisporites antiquasporites</i>			8	3			7	P		3		7	3	3	7	P	
	<i>Umbellatosporites umbellatus</i>		7															
	<i>Umbellatosporites</i> spp.			10	8	P	18	7		3	9		18	7	12			
	<i>Acantobolites verticillatus</i>				9		3	10										
	<i>Acantobolites</i> spp.		3		13		8	43			21		18	10	P	7		
	<i>Heliosporites saemensis</i>																	
	<i>Chamaecolites wallmanni</i>		P				9	P			12	P		10		7		
	<i>Acaulacricolites truncatus</i>																	
	<i>Acutatosporites communis</i>											P						
	<i>Leptolepidites verrucosus</i>																	
	<i>Convolvosporites</i> sp.			P	3	P		7	3		6		7		P			
	<i>Lithomysporites adaeus</i>			3														
	<i>Nettrilites austroclavellatus</i>				P			3	10		3		4	10	183	3		
	<i>Nettrilites minor</i>																	
	<i>Nettrilites</i> spp.				8					7					18			
	<i>Cicatricosporites halleyi</i>			P						3	3		4					
	<i>Triletes bellianus</i>			P		P												
	<i>Taurocuspites radicans</i>			P	3	7		P	P	3		24						
	<i>Taurocuspites segmentatus</i>																	
	<i>Gleichenoidites saemensis</i>		P	19	3	P	P	P	10	P	3		4	10	P	7		
	<i>Chamaezomsporites isoponis</i>												4				P	
	<i>Cingulites clavus</i>																	
	<i>Foramsporites unithapensis</i>		10	3	6	P	3	10	10		9	P	7		15	P		
	<i>Zlivisporites novaezicaneus</i>		P	10	6	10	6	7	6	7	15				3	7		
	<i>Laevigatosporites adiscordatus</i>		3															
	<i>Laevigatosporites discordatus</i>		3	3		3	3			7				7		3		
	<i>Laevigatosporites druggii</i>			P					P									
	<i>Laevigatosporites ovatus</i>		7	10	9	3	15	7	37	P	9	P	7	10	6	7		
	<i>Polypodisporites amplus</i>																	
	<i>Aequitriradites spirulosus</i>						P	3			9		4					
	<i>Aequitriradites ornatus</i>				3													
	<i>Vittisporites pallidus</i>		3	3	3	7	3	P	3	P	3		7	10	6			
	<i>Alisporites bilateralis</i>			3	P	10		P	P	P			4		P	3		
	<i>Alisporites</i> spp.		3	3		7			3		3		7		6			
	<i>Cedripites cretaceus</i>		7	3	3	17	3	P	3	3	P		7					
	<i>Parvisaccites radiatus</i>		P		3	17	P		10	3	12		7	3	9	3		
	<i>Lygistosporites</i> sp.				P				3									
	<i>Podocarpidites ornatus</i>		3		6	10	3				10							
	<i>Podocarpidites</i> spp.				P				P	P			14	3	3	6		
	<i>Pityosporites</i> sp.				P				P	P								
	<i>Pityosporites</i> sp.					3			P	7	P							
	<i>Taxodiaceosporites hiatus</i>		65	67	314	31	46	50	60	47	30	P	29	20	55	60	P	
	<i>Equisetitesporites multicastratus</i>			10	6	3		3	3	17	8		7	3	12			
	<i>Cycadospites nitidus</i>		63	35	9	10	18	27	34	10	15		11	16	27	22	P	
	<i>Liliacoidites nitrus</i>		P	P	3			P	6		6		3	6	3			
	<i>Liliacoidites morrenensis</i>		3	10	6				P		3	P		3	6			
	<i>Liliacoidites verticatus</i>			3					P					3				
	<i>Liliacoidites</i> spp.		33	51	13	3		23	28	27	45		23	21	32			
	<i>Neupreacoidites amulatus</i>		3		P			3					4					
	<i>Neupreacoidites oculatus</i>				3	P		7	P					P				
	<i>Ceroidiphyllites brevicolatus</i>				P						3		4					
	<i>Cramellia striata</i>		P	8	31	3	P	P	13	3	12		10	3	7			
	<i>Grewiapollenites canadensis</i>		P		6				3	3			7	6				
	<i>Loranthoidites catterallii</i>																	
	<i>Agutricolpites vulgarens</i>		P	3	3	P		3	P	3	3		4		3	P		
	<i>Tricolpites parvistratus</i>		7	P		P			6	3	3		7	3	P			
	<i>Tricolpites reticulatus</i>		3		P	3			3		P		3	P	3	P		
	<i>Tricolpites sagax</i>				P	P			10									
	<i>Tricolpites striatus</i>							3						3	3			
	<i>Pentatropites mollii</i>		3	P	P		P	7	10		3			3	3			
	<i>Aquilapollenites amplus</i>		P	6	6	3		P	10	P				P	3	P		
	<i>Aquilapollenites exar</i>			P		3		3		3			4	3	3			
	<i>Aquilapollenites attenuatus</i>		P		6	P	P		6	7	6	P		3	6	3		
	<i>Aquilapollenites calvus</i>		3	P	6	P	P	P	6	7	6	P		3	P	3		
	<i>Aquilapollenites clavigraticulatus</i>		3	P	P						3							
	<i>Aquilapollenites pyriformis</i>								P	P	P		4		3			
	<i>Aquilapollenites quadrilobus</i>		P	P		3	P	P	P		3	P			3	3		
	<i>Aquilapollenites reticulatus</i>		P	6		3	3	7	3	3	6		4	3	12	3		
	<i>Aquilapollenites triolatus</i>		6	13	3	3	3	7	3	3	6							
	<i>Aquilapollenites trioliformis</i>				9			3	10		6							
	<i>Aquilapollenites turbidus</i>		10	6	3	3	15	7	P	3	3			7	3	3	P	
	<i>Aquilapollenites</i> spp.		50	41	18	45	43	33	28	7	42		50	20	57	10		
	<i>Montenapollis endannulatus</i>								P				4					
	<i>Pulcheripollenites narcissus</i>				3													
	<i>Santipites drumhellerensis</i>																	
	<i>Symplocarpipollenites vestibulum</i>																	
	<i>Proteacidites thalassii</i>		P				3									3		
	<i>Triatriopollenites costatus</i>		3	3	P				P	10	3		4		P			
	<i>Triopropollenites rufatus</i>		10	6	P	7			10	10			4	7	15	18		
	<i>Trudopollis meekerii</i>					3	9											
	<i>Erdemipollis procumbentiformis</i>			3		3												
	<i>Schizosporites parvus</i>								P		P							
	<i>Schizosporites</i> spp.		17	8	13	7	24		8	10	3	P	7	3		7		
	<i>Stigmodipollis hispidus</i>		3	3	3	3			P	3	9				3			
	<i>Trilete spores Indes.</i>		78	118	48	86	101	184	77	100	193		187	145	49	134		
	<i>Nonulata spores Indes.</i>		59	82	48	69	103	53	97	98	48		56	78	55	118		
	<i>Blascatte Indes.</i>		32	6	28	118	61	60	28	29	55		74	20	31	11		
	C1		170	103	99	96	132	107	91	165	79		60	157	91	153		
	C3		173	60	38	72	27	17	120	93	38		42	55	109	99		
	C3P		40	70	71	59	77	37	71	73	30		42	42	36	23		
	Unknowns		92	153	93	265	218	175	126	208	172		242	239	100	190		
	Fungal/Algal		P	P	P	P	P	P	P	P	P		P	P	P	P	P	
	Neosporites		P	P	P	P	P	P	P	P	P		P	P	P	P	P	

TABLE I. PERCENT RELATIVE ABUNDANCE OF PALYNOMORPHS RECOVERED FROM THE TURTLE MATRIX SAMPLES (S) ARRANGED WITHIN TIERS (T) A,B,C,D. P INDICATES PRESENCE BUT NOT ENCOUNTERED DURING THE COUNTS.

given sample (via the initial slide scan analysis) but was not encountered in the counts the letter "P" (present) is indicated in the appropriate place.

Several generalized categories are incorporated within the counts and include: C_3P_3 (tricolporate dicotyledon pollen); C_1 (monocolpate or monosulcate pollen); unknown bisaccate gymnosperm pollen; unknown trilete spores (ferns, mosses, liverworts); unknown monolet spores (usually always polypodiaceous), and other unknowns, not assignable to one of the preceding categories.

In addition to the tabulation of identified taxa and specimens within the generalized unknown categories, the presence of algae, and/or fungal elements and megaspores were noted as present or absent within each sample.

Fungal and algae elements are present in most samples, usually in very low numbers. However the following samples contained sufficient numbers to warrant comment. The turtle matrix samples typically contained fewer fungal/algal material than did the sediment outcrop samples. The number of fungal elements encountered in a count of 300 are given in parenthesis following the sample number: 0187(6), 0192(5), 0196(18), 0173(6), 0178/4(24), and 0178/5(16).

Fungal elements were identified to form genus by comparison to published descriptions and illustrations in Clarke (1965), Elsik (1968) and Van der Hammen (1954). The following genera are tentatively identified from the Dinosaur Provincial Park samples:

Diporicellaesporites Elsik, *Dyadosporites* Van der Hammen ex Clarke,
Fractisporonites Clarke, *Microsporonites* Jain, *Pluricellaesporites* Van der Hammen
and *Ruduviasporonites* Wilson.

Because of the processing techniques used in this study, only very small megaspores, of less than 150 μ m largest dimension were recovered. Suitable procedures for the recovery of megaspores are outlined in Wall *et al.* (1971). Megaspore taxa which are identified from the Dinosaur Provincial Park samples include *Azolla* Lamarack, *Balmeisporites* Cookson and Dettmann and *Ghosispora* Srivastava (see Srivastava 1971b; 1978). Megaspores are not included within the palynomorph counts in that their presence or absence can not be related to diversity or relative abundance due to the selective processing procedures. Megaspores are most abundant in the following samples (number in parenthesis indicates the number of individuals encountered in a count of 300); 0182(6), 0189(6), 0196(9), 0171(11), 0178/4(8), 0179/2(12).

Inspection of Tables I and II reveals several points worthy of discussion here. Within

both the turtle matrix samples and sediment samples six taxa are co-dominants, that is they occur with greater frequency within most samples. These taxa include the ferns *Cyathidites minor* (as frequent as 6.2% in sample 0179/2) and *Laevigatosporites ovatus* (3.7% in sample 0197), the gymnosperms *Tazodiaceapollenites hiatus* (as high as 31.4% in sample 0191) and *Cycadopites nitidus* (with 6.3% in sample 0182) and the angiosperms *Liliacidites* spp (up to 5.1% in sample 0198), *Aquilapollenites* spp (with 10.6% in sample 0173) and *Triporopollenites rugatus* (represented by as much as 5.4% of sample 0179/2).

There appears to be no significant differences in the composition and relative abundance of taxa between the turtle matrix and sediment samples. Further, there does not appear to be any significant differences in composition and abundance between samples within each group of samples. This point is graphically illustrated in Figures 3 through 25. These graphs plot the ratios of relative abundance of (a) selected plant groups (i.e. fern vs. gymnosperms) (b) plant groups vs total flora (i.e. fern vs. total flora) and (c) selected pollen taxa (i.e. *Laevigatosporites ovatus* vs. *Aquilapollenites* total).

The taxa and plant groups were selected on their apparent importance within the flora. The variation within these ratios does not appear to be noteworthy, yet mathematical tests may demonstrate if the variation as recorded in the graphs is significant. The samples are relatively homogeneous in their floristic composition, which would be expected within a given local flora covering essentially one contemporaneous time horizon. A geographically broader sampling base and/or covering a longer stratigraphic interval may indeed detect greater and more significant floristic changes.

An interesting relationship exists between the number of monolete vs. trilete spore types within a given locality.

Wagner (1974) discussing the work of Ito (1972) noted that the ratio of monolete to trilete spores (m:t) can be correlated with geography. The values of m:t increase with latitude and elevation. Examples of this correlation cited by Wagner include the following values: Philippine Islands m:t = 1.27, Eastern Himalay m:t = 2.71. Wagner however cautioned that local variation and peculiarities must be taken into consideration. For example the m:t value for the State of Michigan (a fairly representative area of northern temperate forest) was 1.74! This value is much less than would be expected, but understandable and results from the very rich species diversity of the ophioglossid forms (trilete) in the Great Lakes Region.

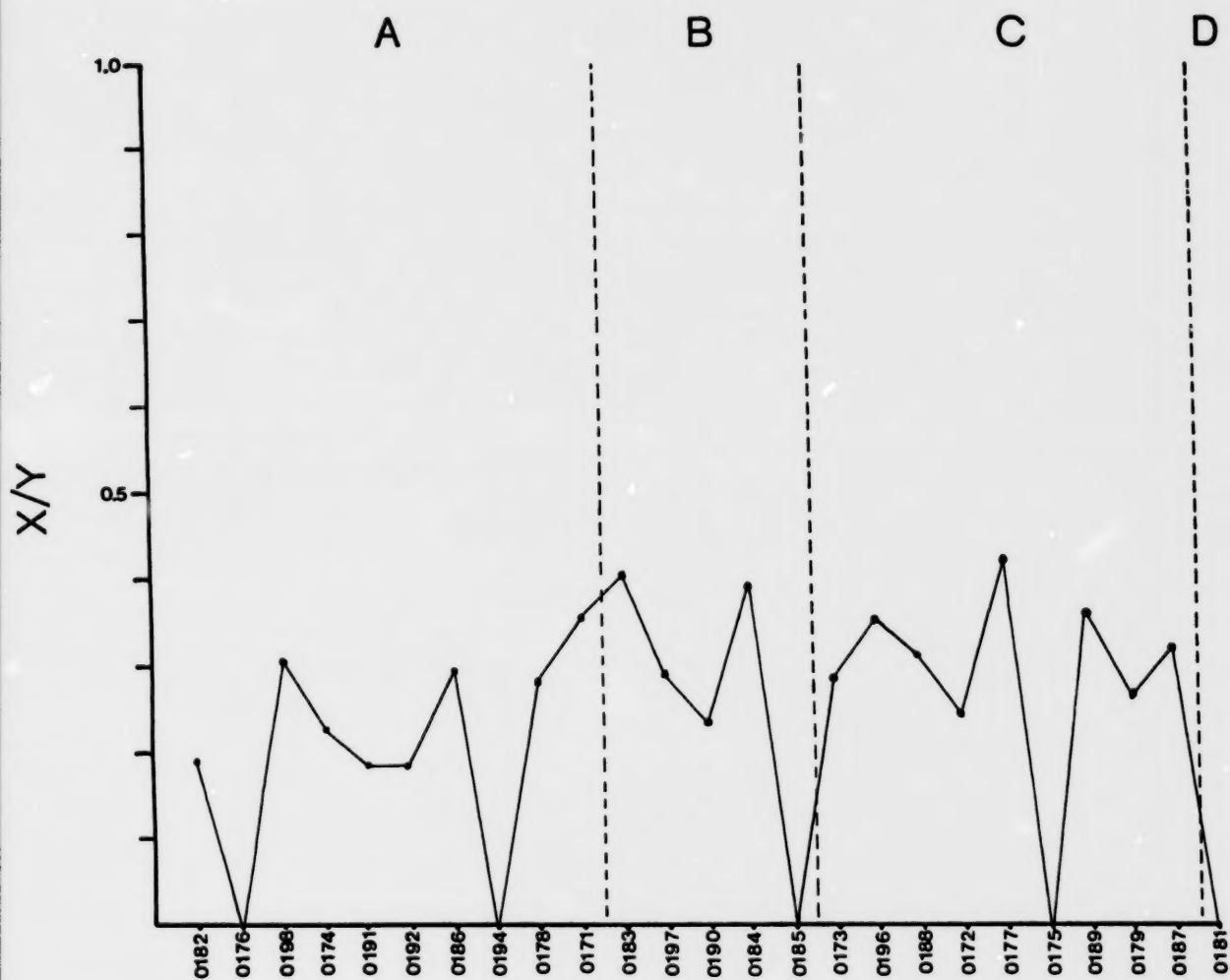


FIGURE 3. *Fern total vs total flora.*

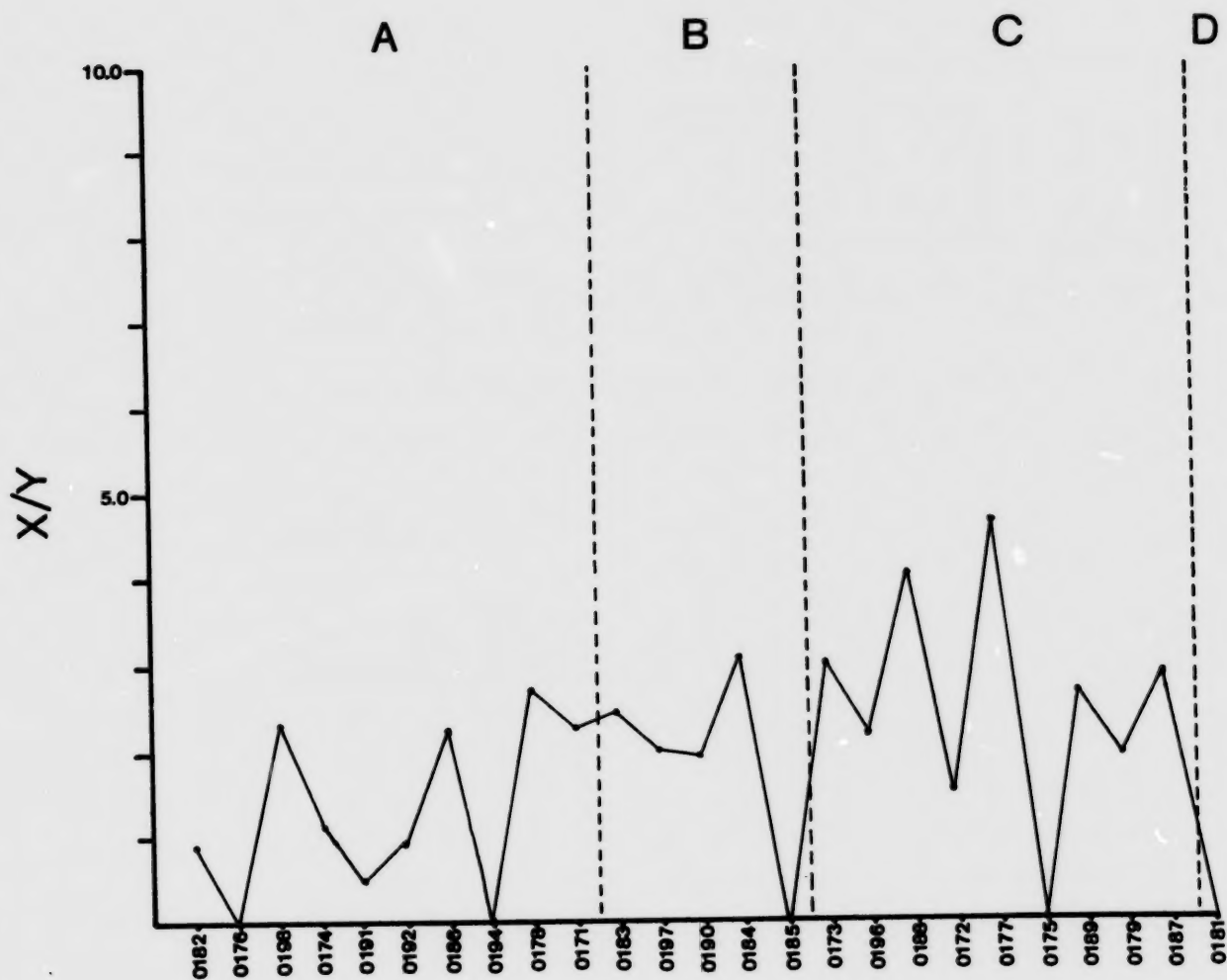


FIGURE 4. *Fern total vs gymnosperm total.*

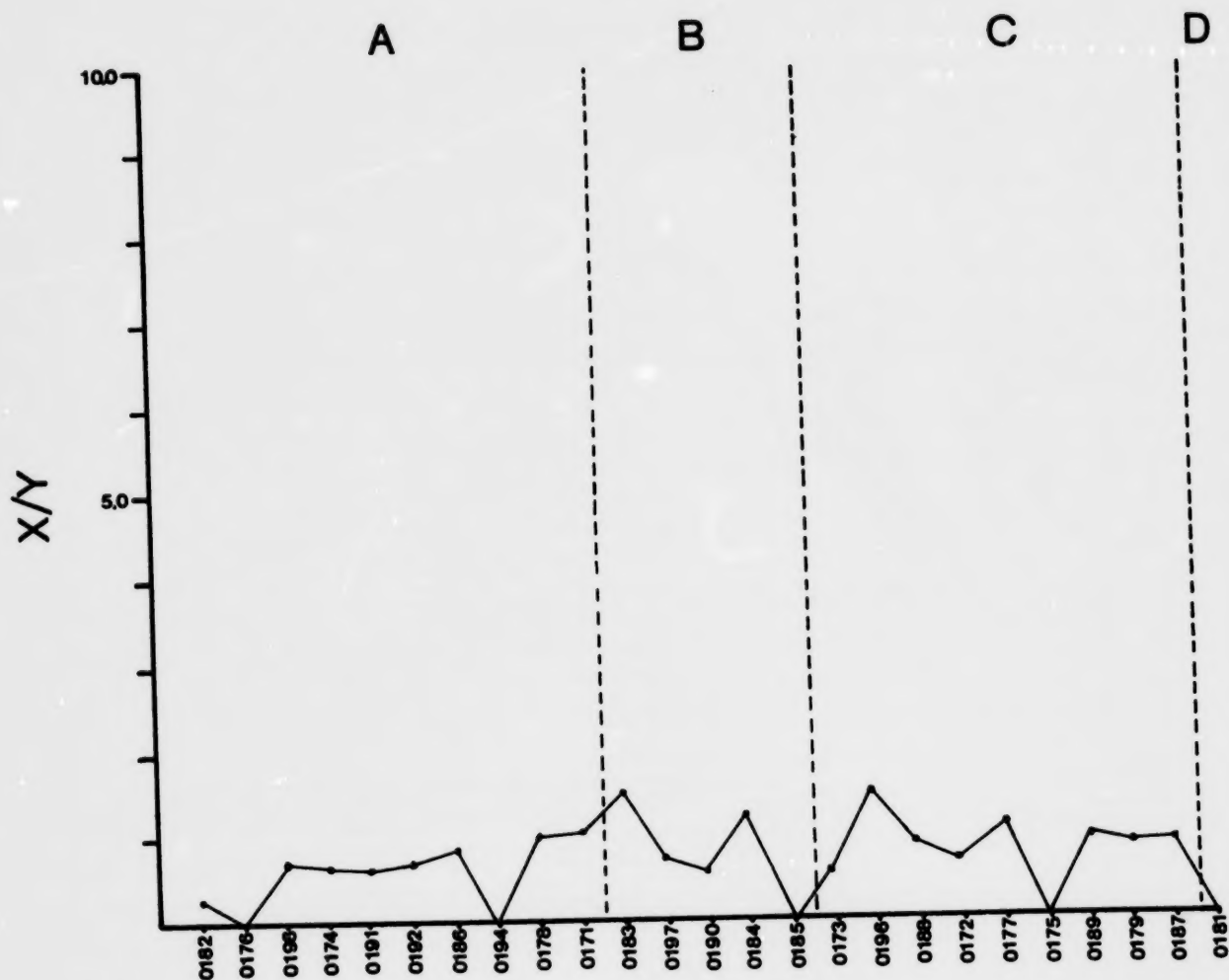


FIGURE 5. *Fern total vs angiosperm total.*

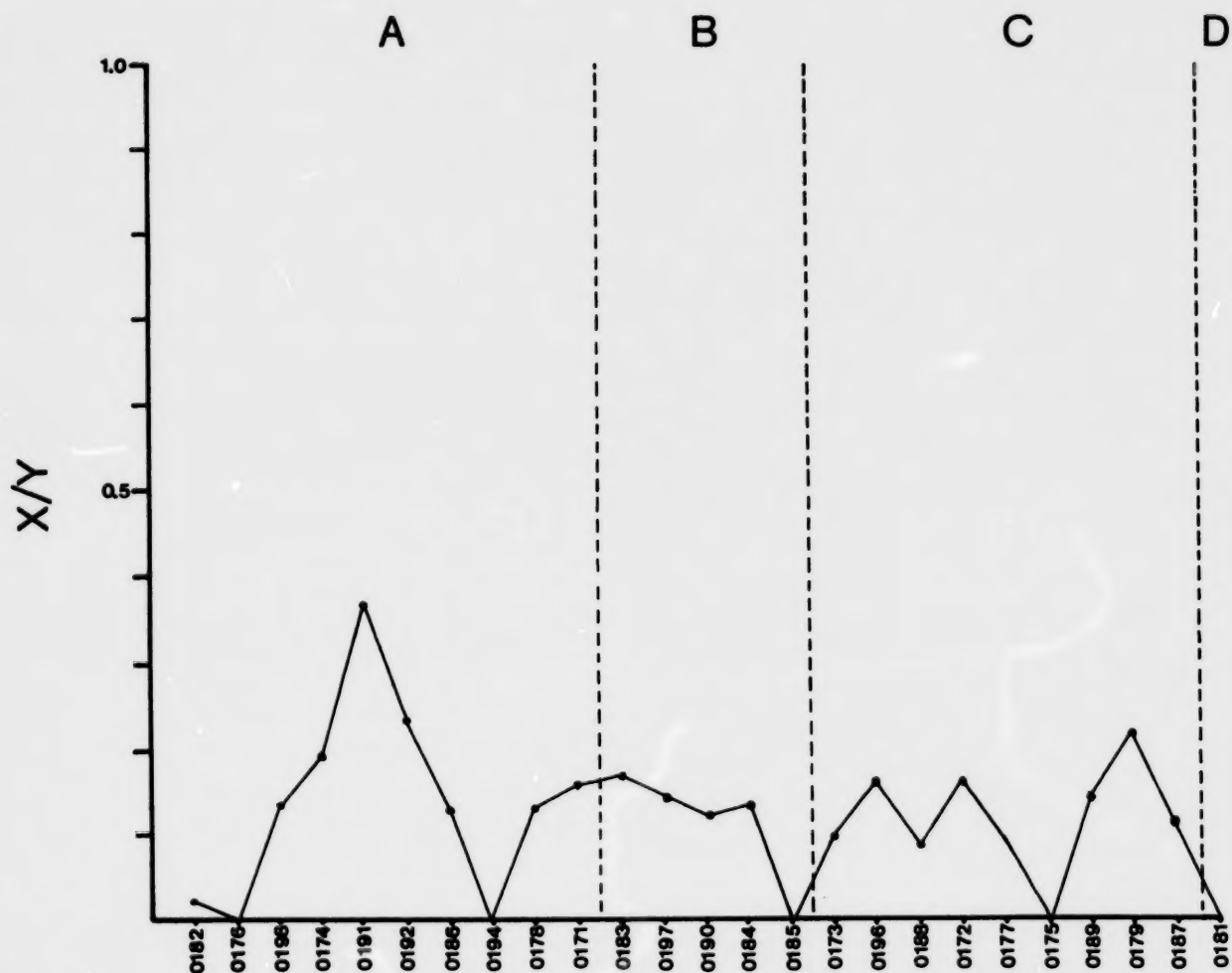


FIGURE 6. *Gymnosperm total vs total flora.*

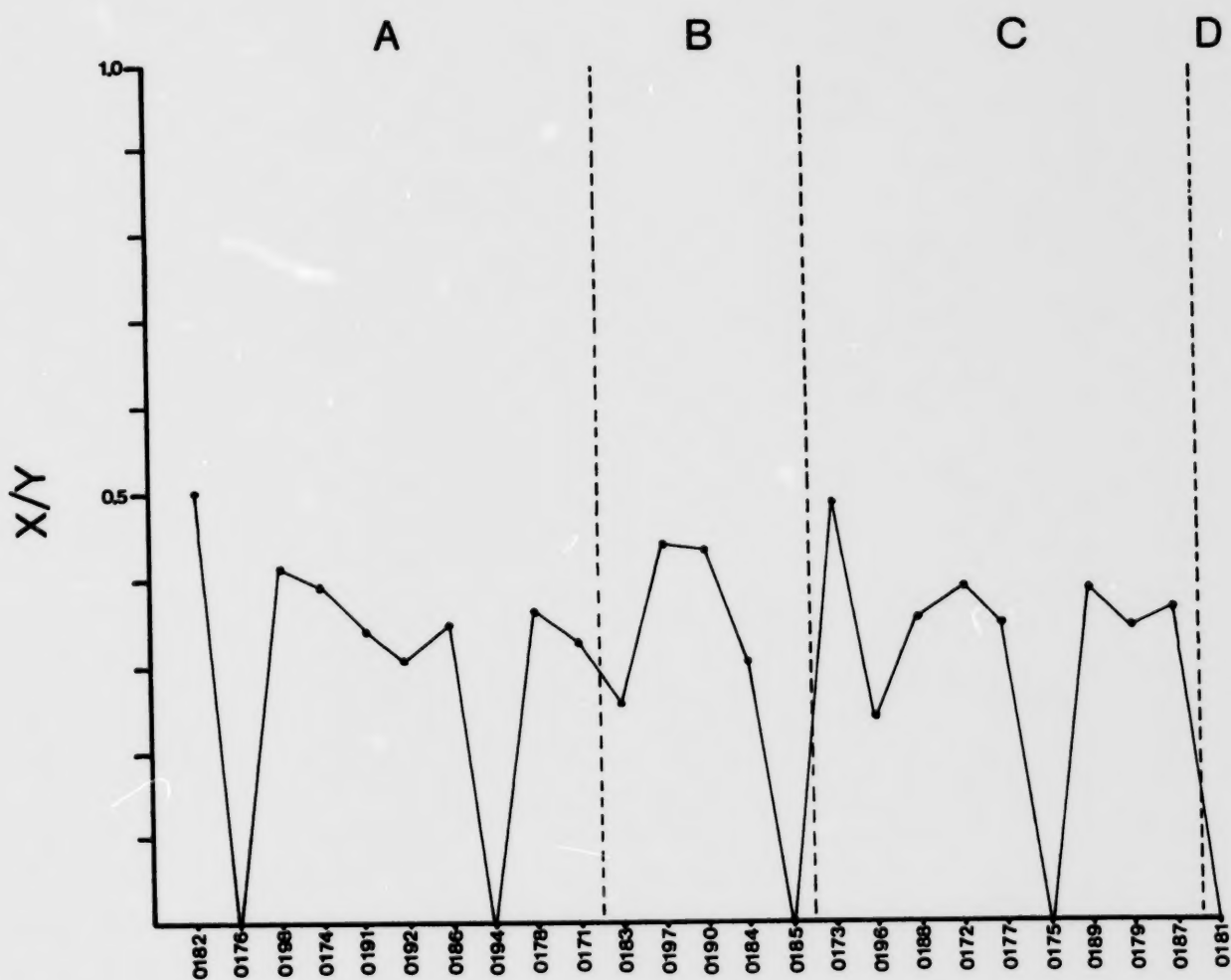


FIGURE 7. *Angiosperm total vs total flora.*

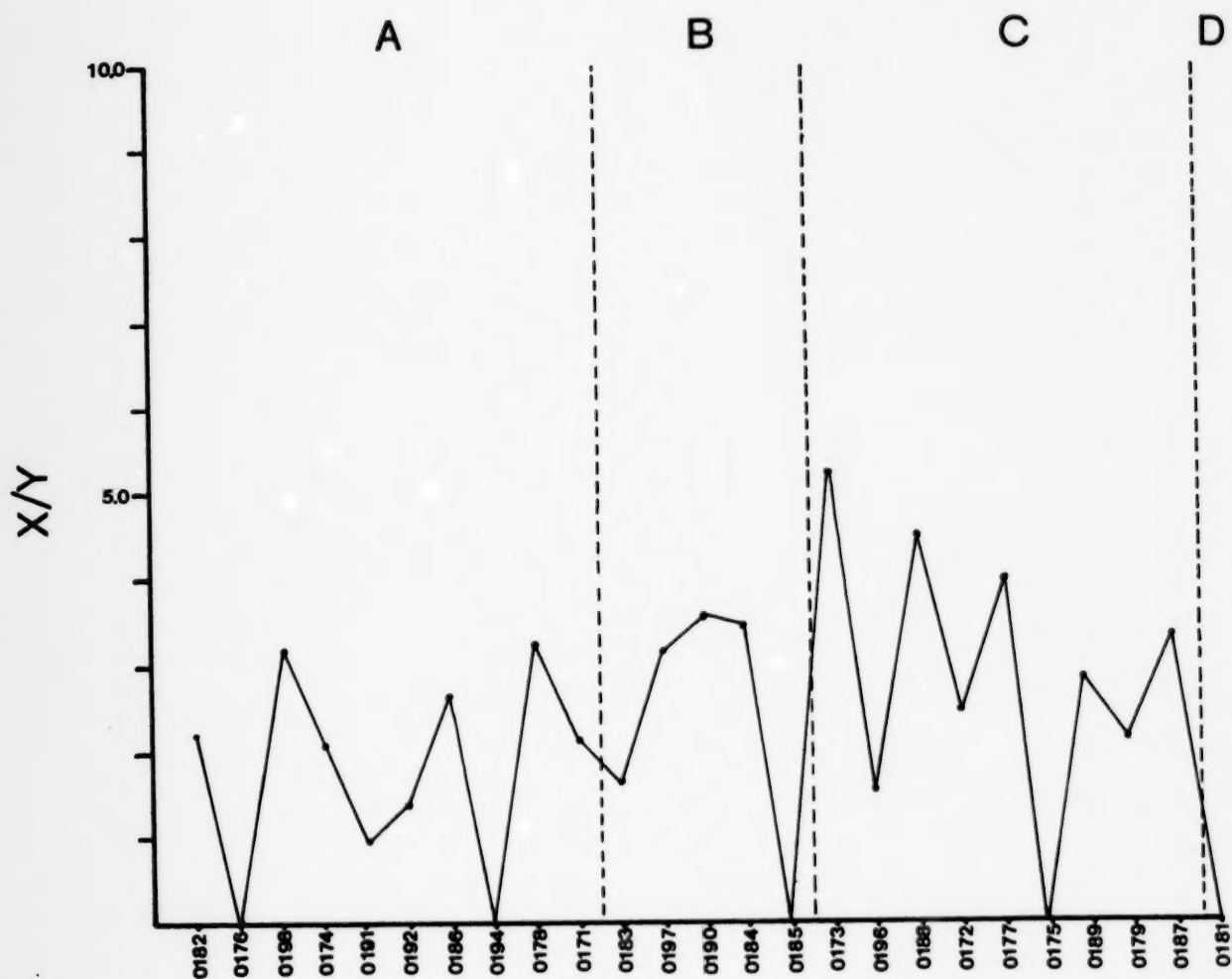


FIGURE 8. *Angiosperm total vs gymnosperm total.*

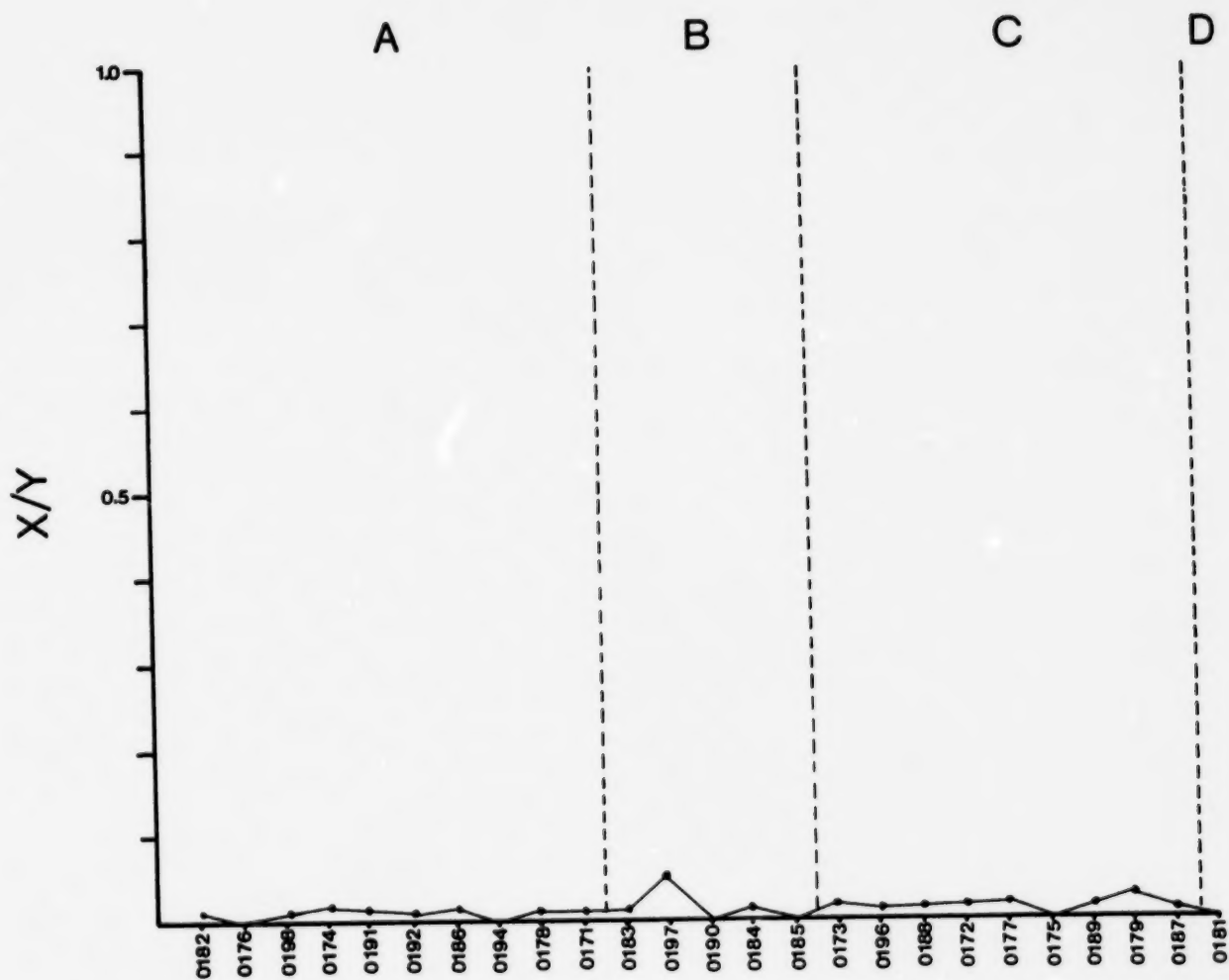


FIGURE 9. *LAEVIGATOSPORITES OVATUS* vs total flora.

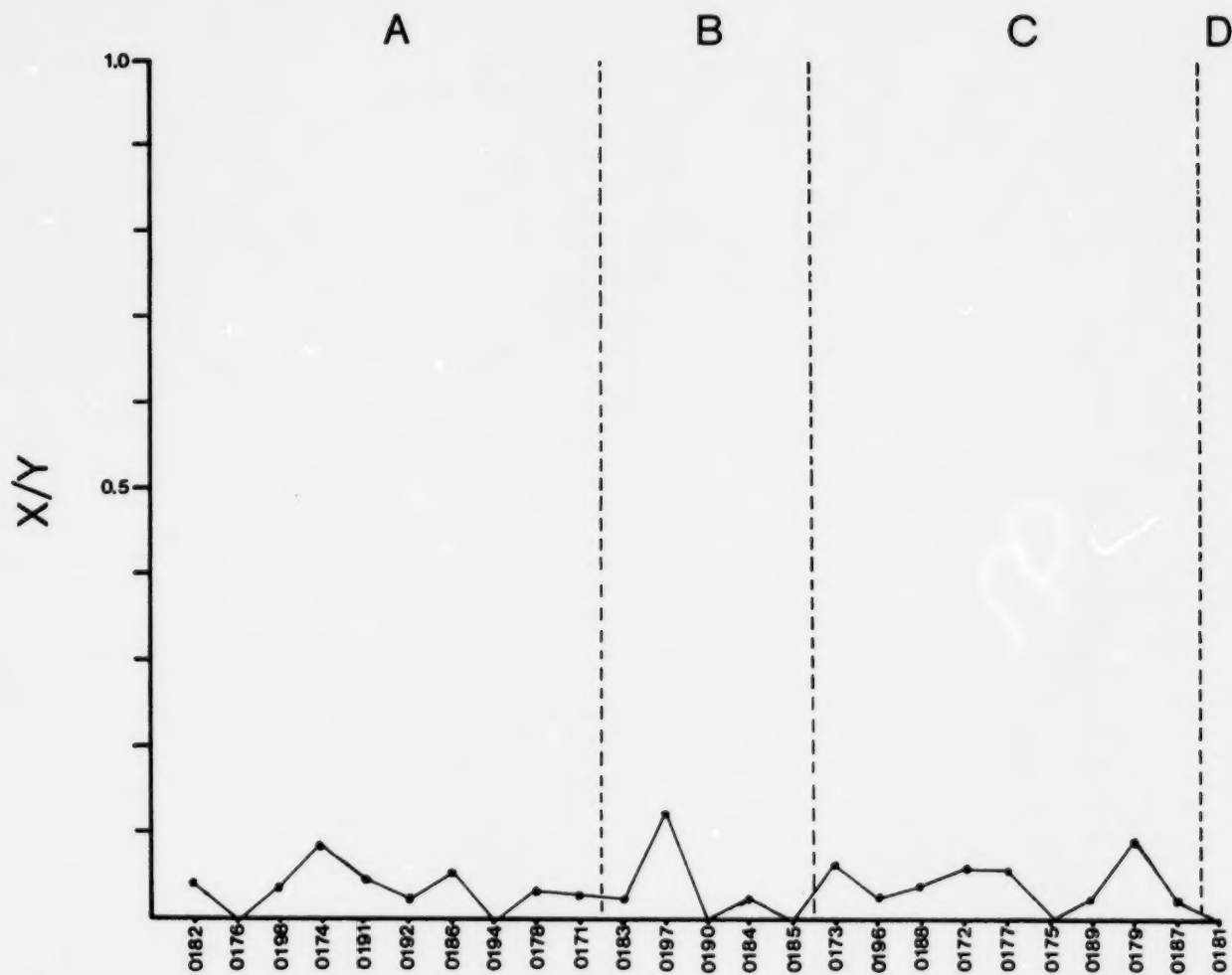


FIGURE 10. *LAEVIGATOSPORITES OVATUS* vs fern total.

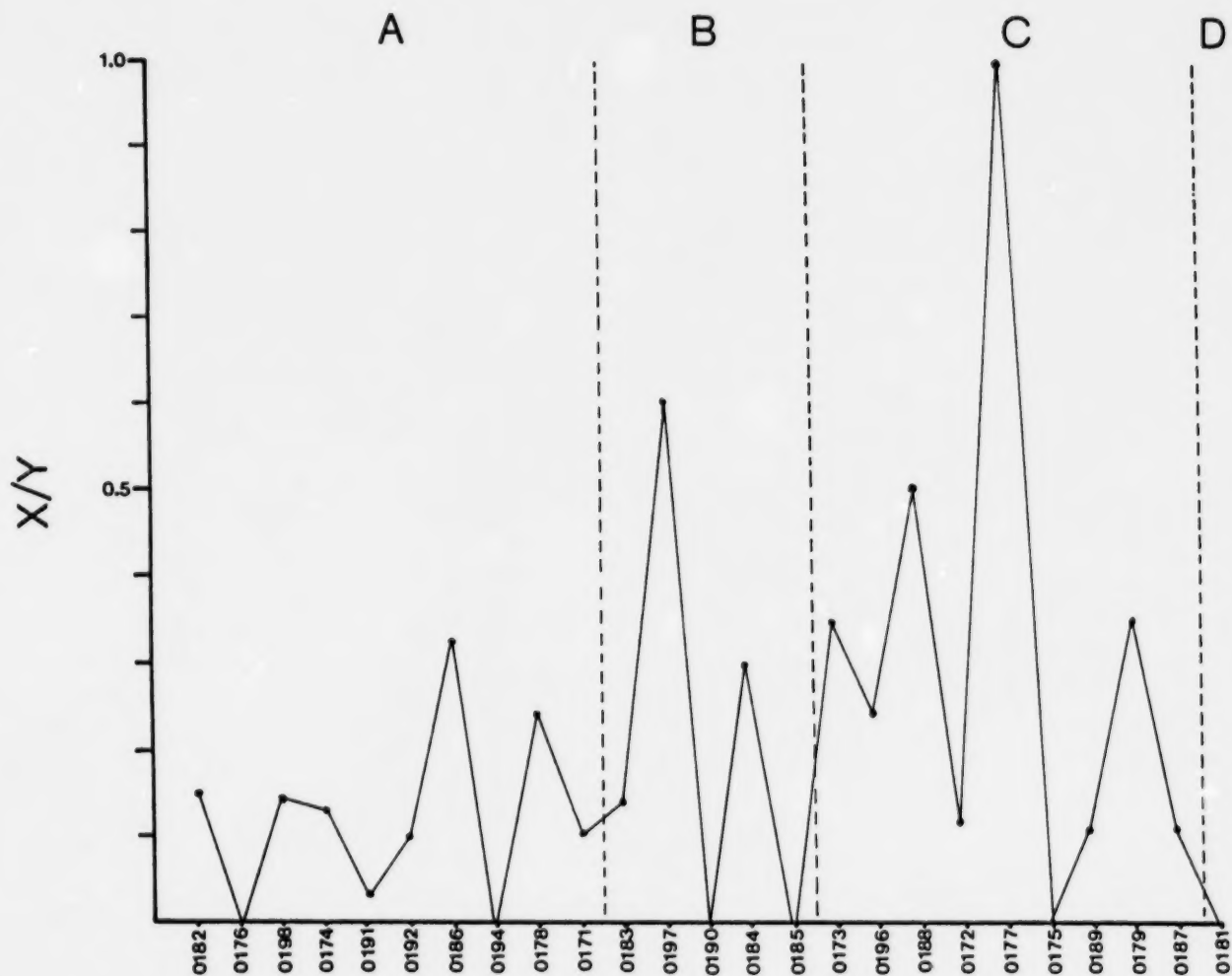


FIGURE 11. *LAEVIGATOSPORITES OVATUS* vs *TAXODIACEAPOLLENITES HIATUS*.

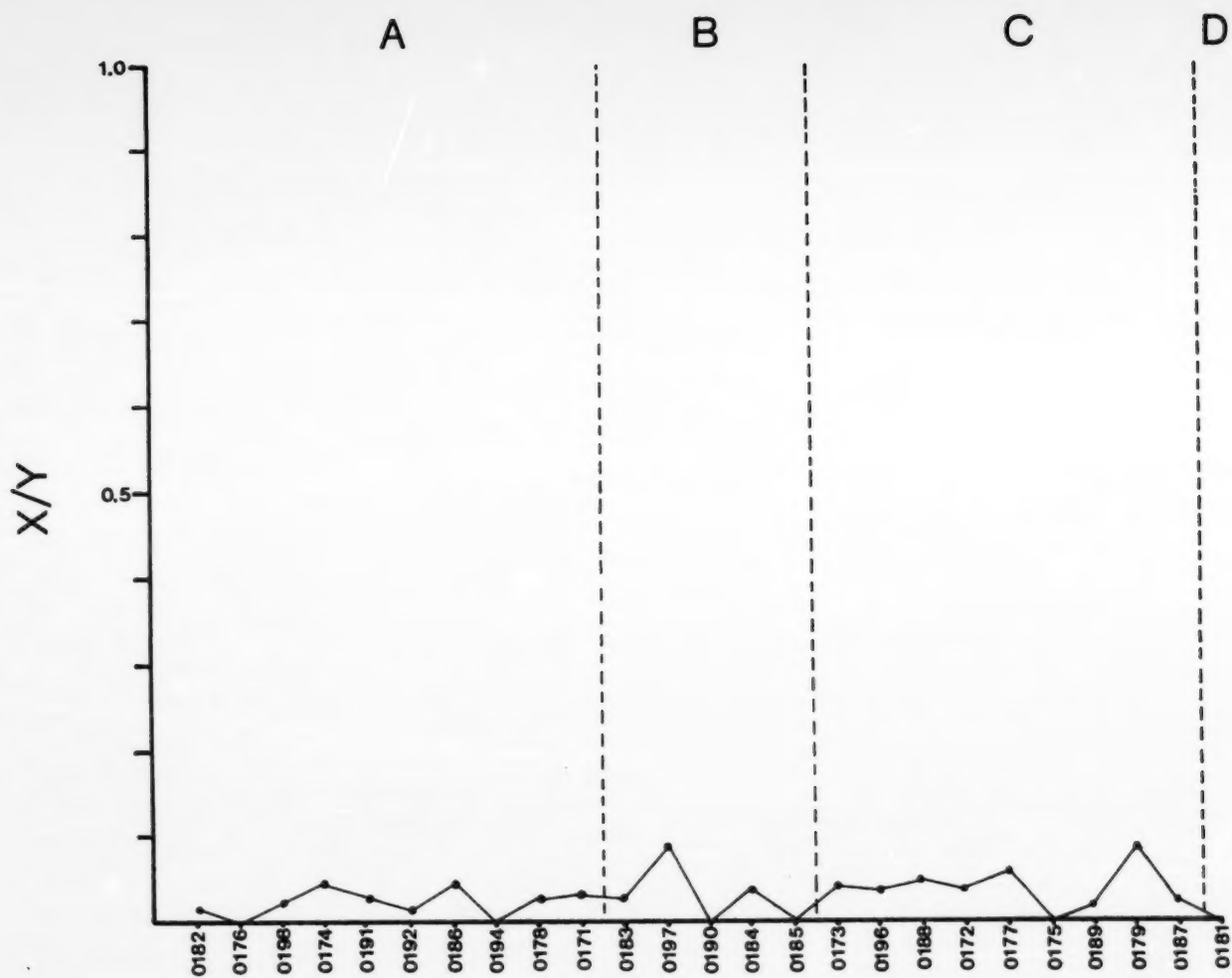


FIGURE 12. *LAEVIGATOSPORITES OVATUS* vs angiosperm total.

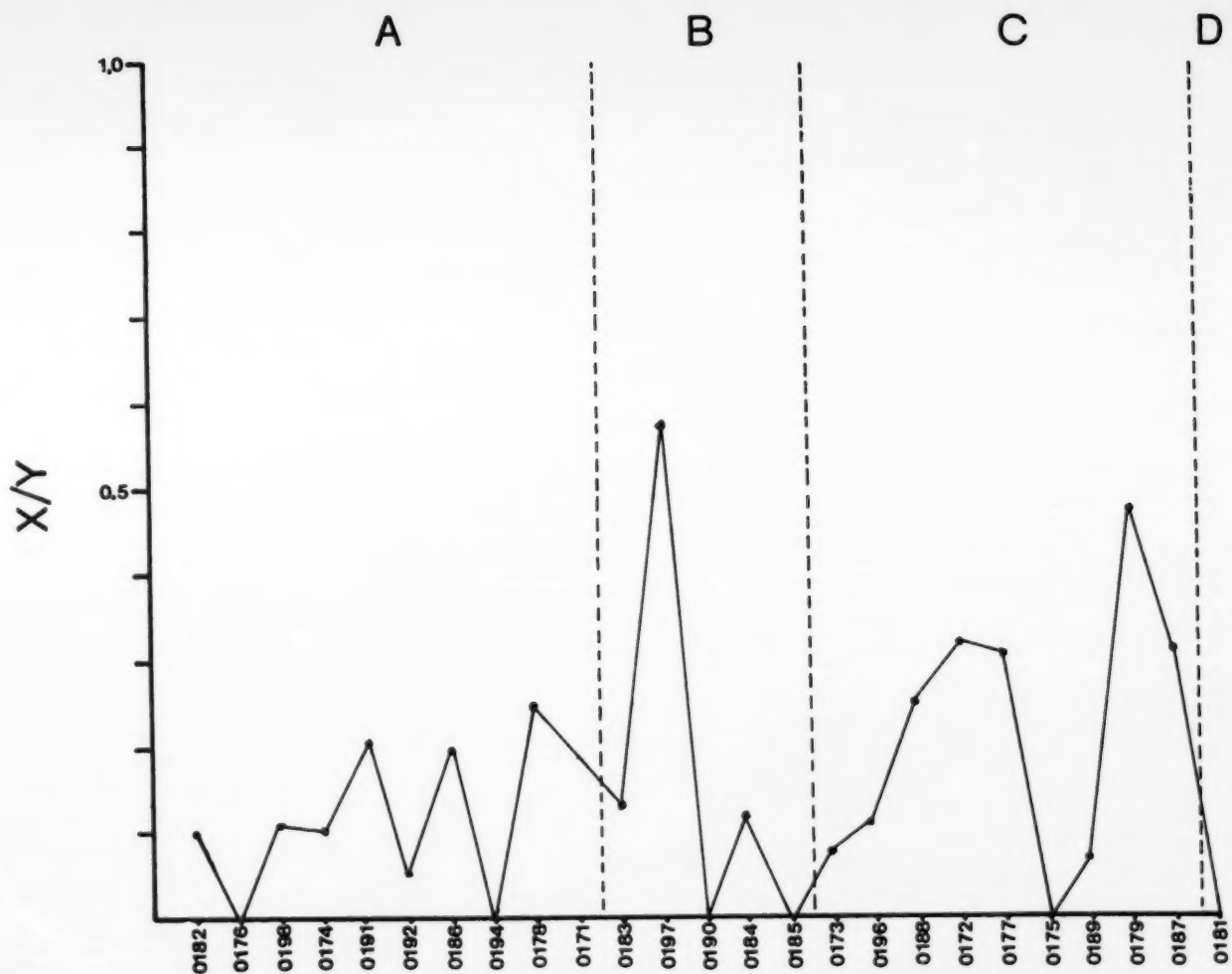


FIGURE 13. *LAEVIGATOSPORITES OVATUS* vs *AQUILAPOLLENITES total*.

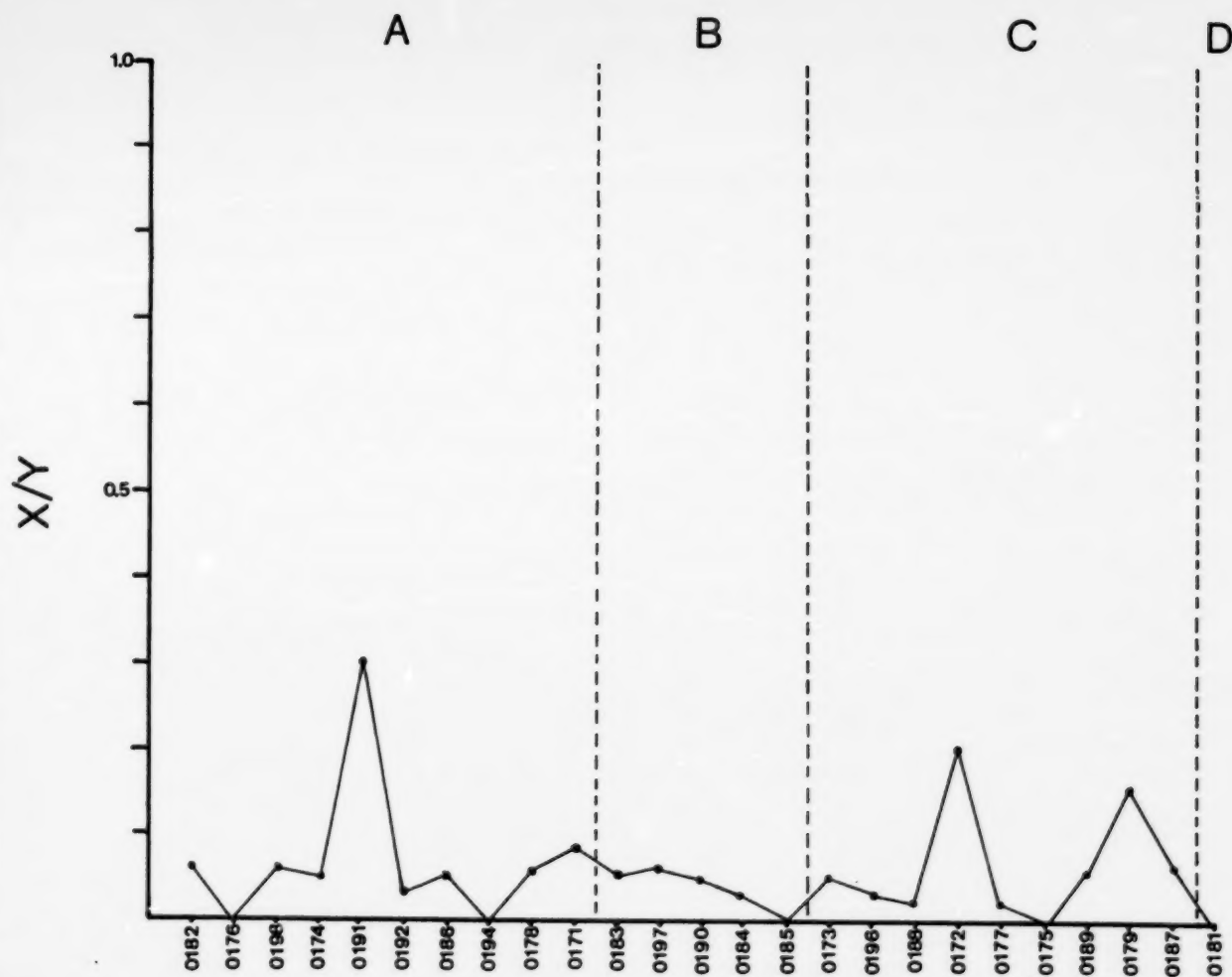


FIGURE 14. *TAXODIACEAE*POLLENITES HIATUS vs total flora.

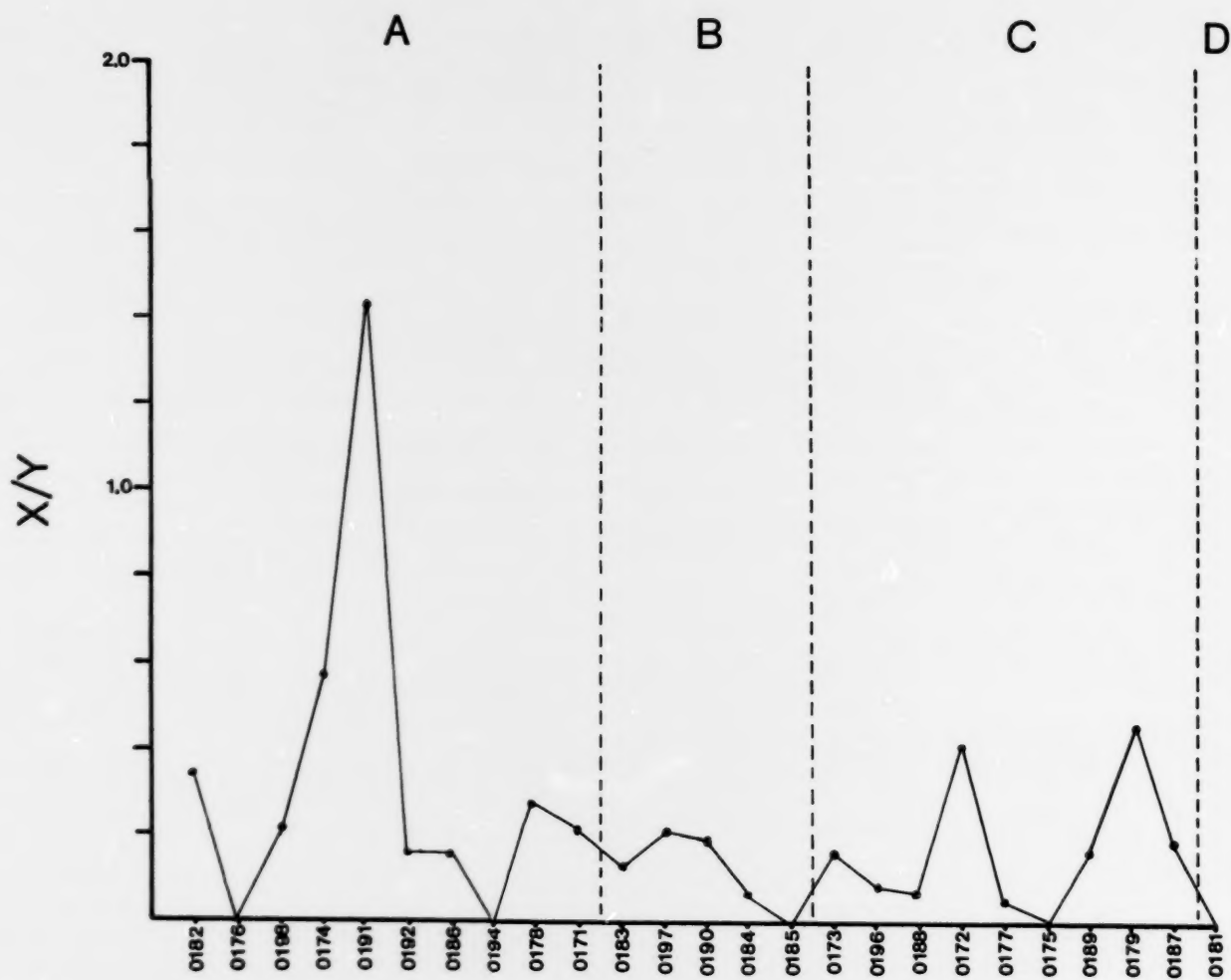


FIGURE 15. *TAXODIACEAPOLLENITES HIATUS* vs fern total.

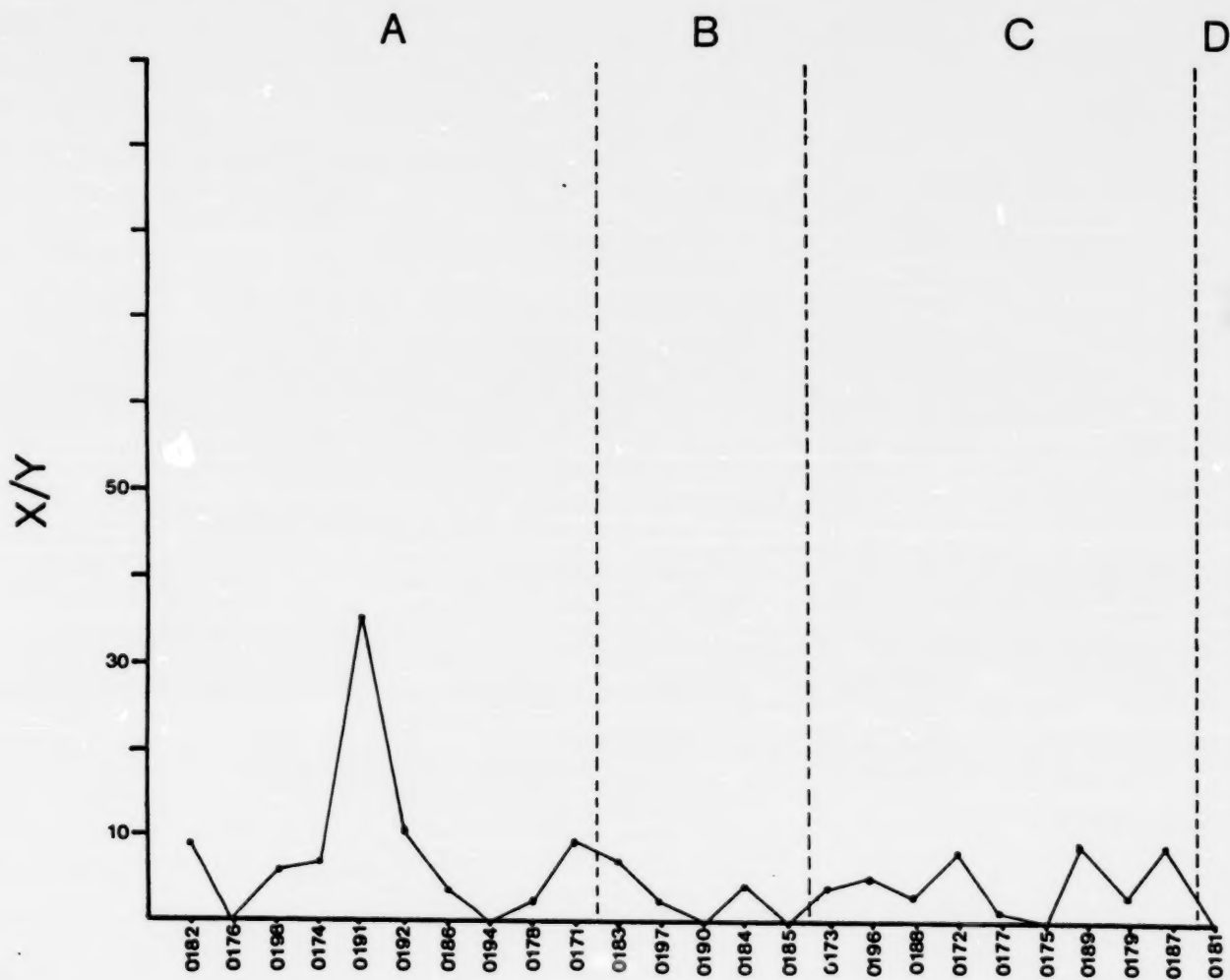


FIGURE 16. *TAXODIACEAPOLLENITES HIATUS* vs *LAEVIGATOSPORITES OVATUS*.

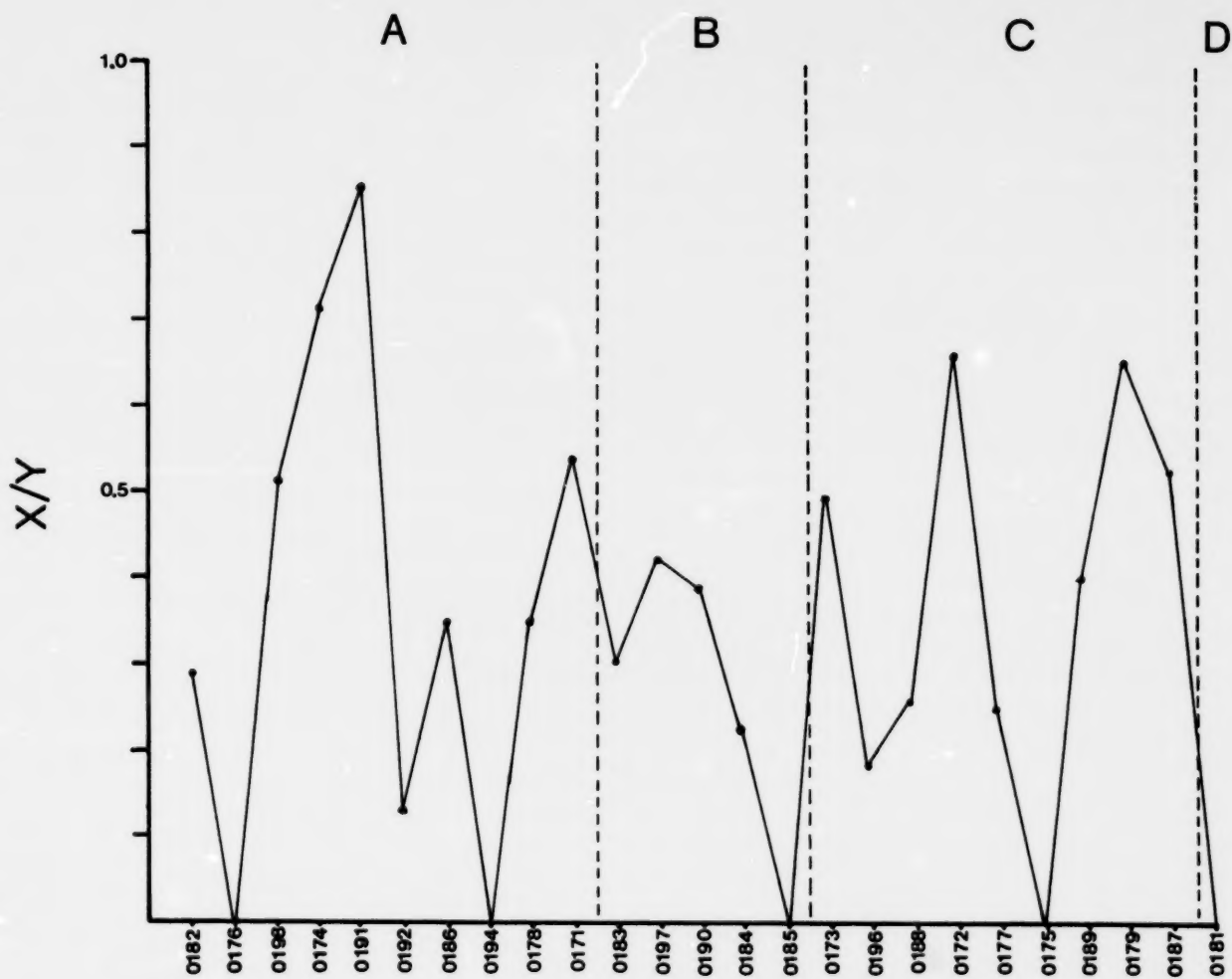


FIGURE 17. *TAXODIACEAEPOLLENITES HIATUS* vs *gymnosperm total*.

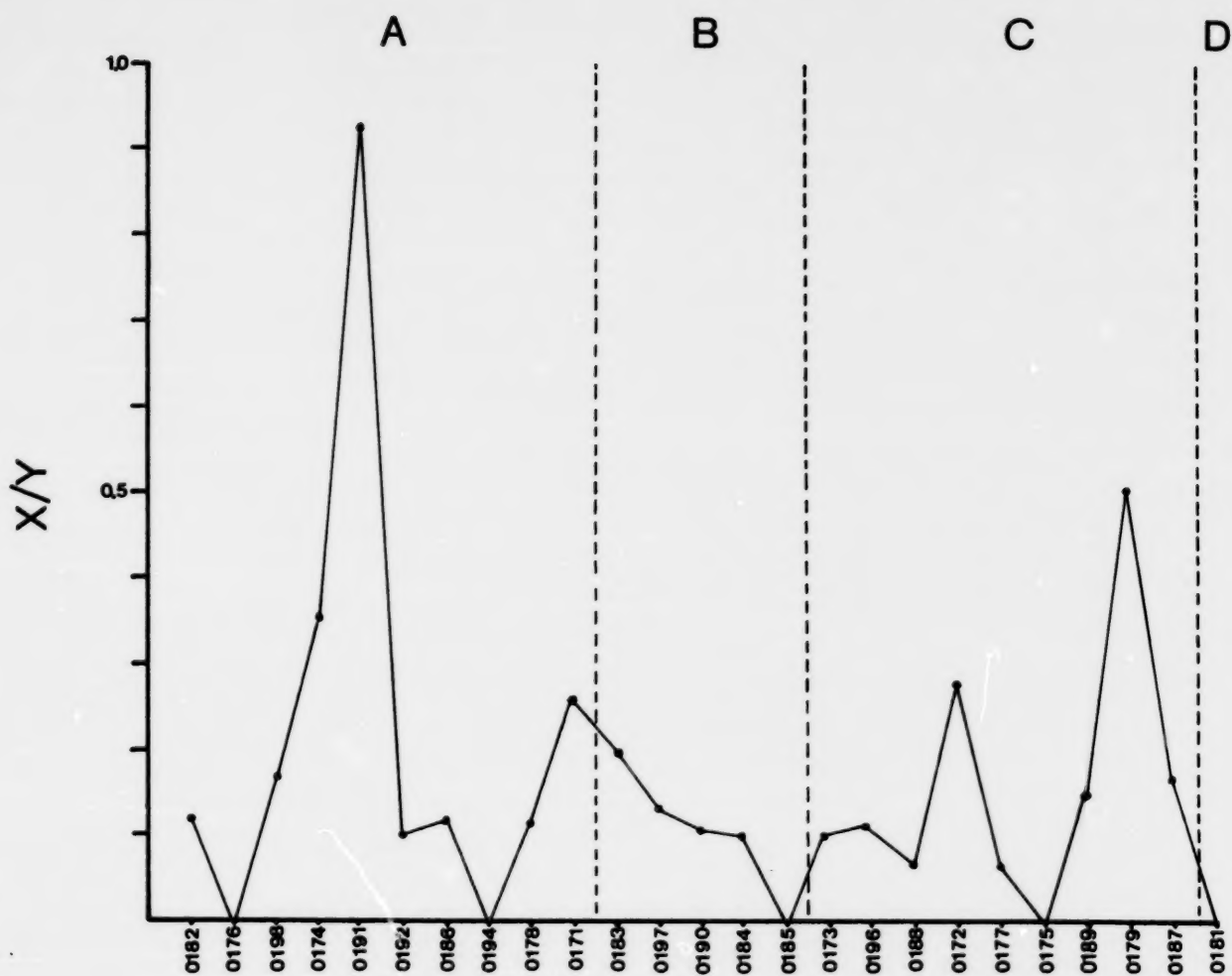


FIGURE 18. *TAXODIACEAEPOLLENITES* HIATUS vs angiosperm total.

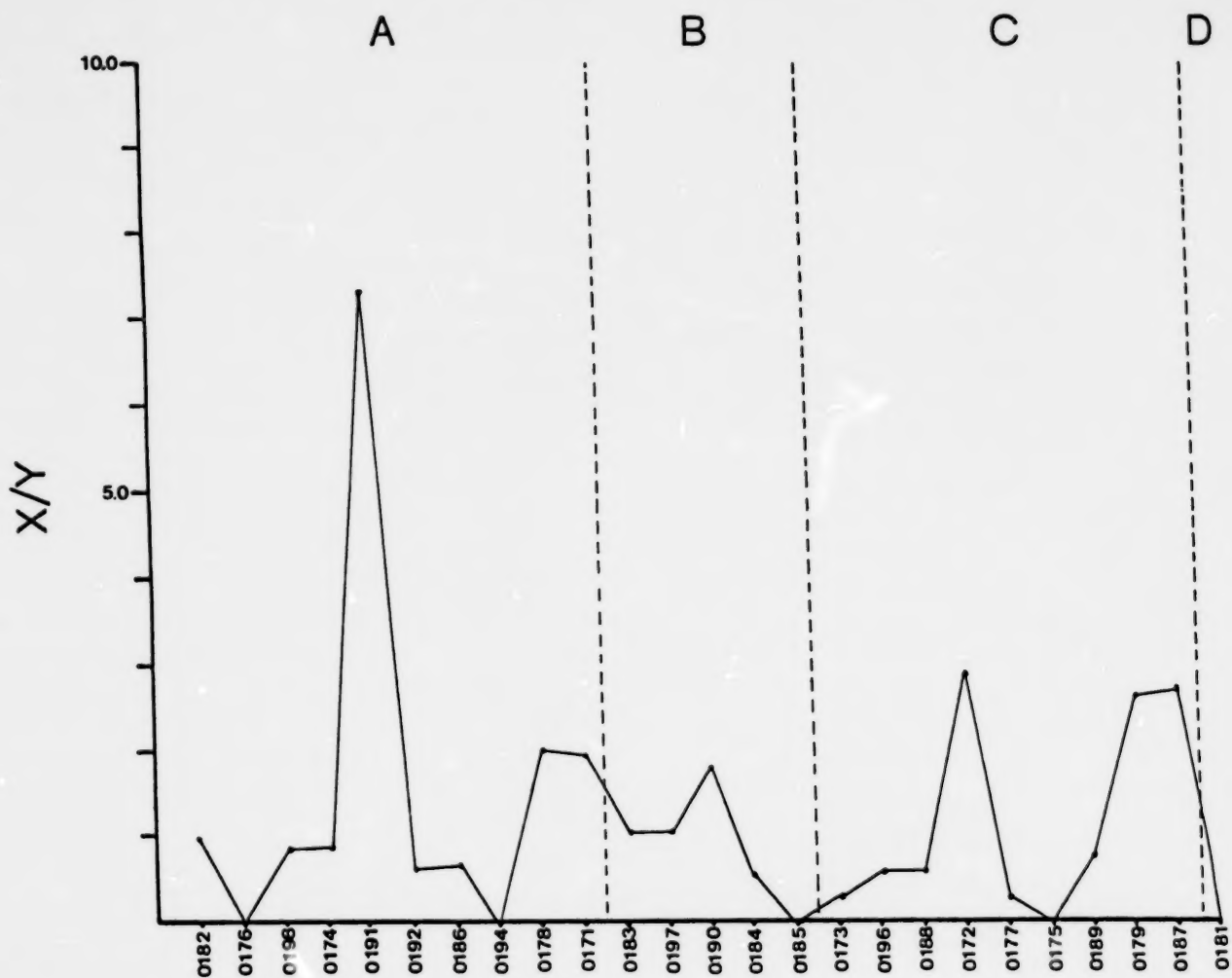


FIGURE 19. *TAXODIACEAE*POLLENITES HIATUS vs *AQUILAPOLLENITES* total.

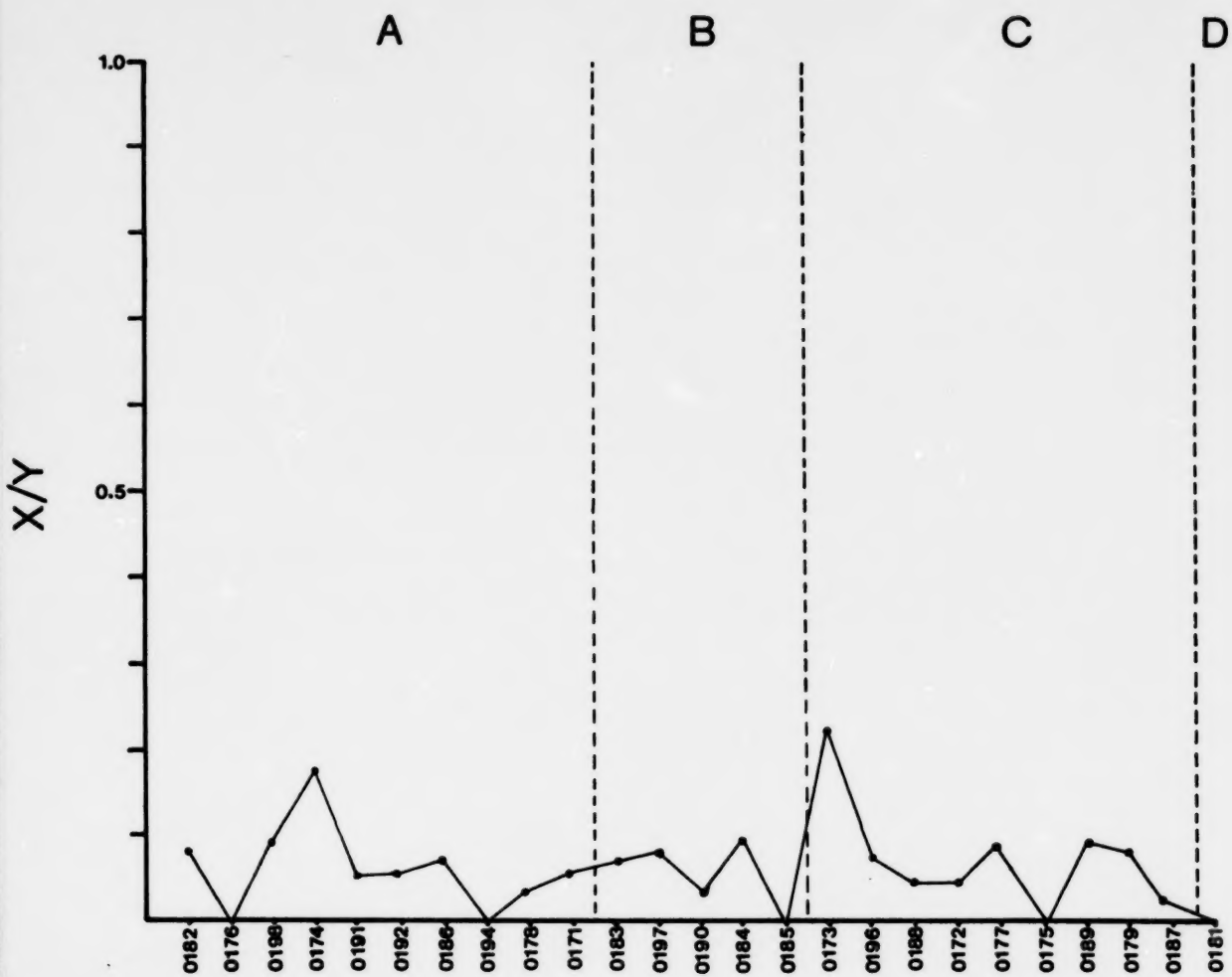


FIGURE 20. *AQUILAPOLLENITES* total vs total flora.

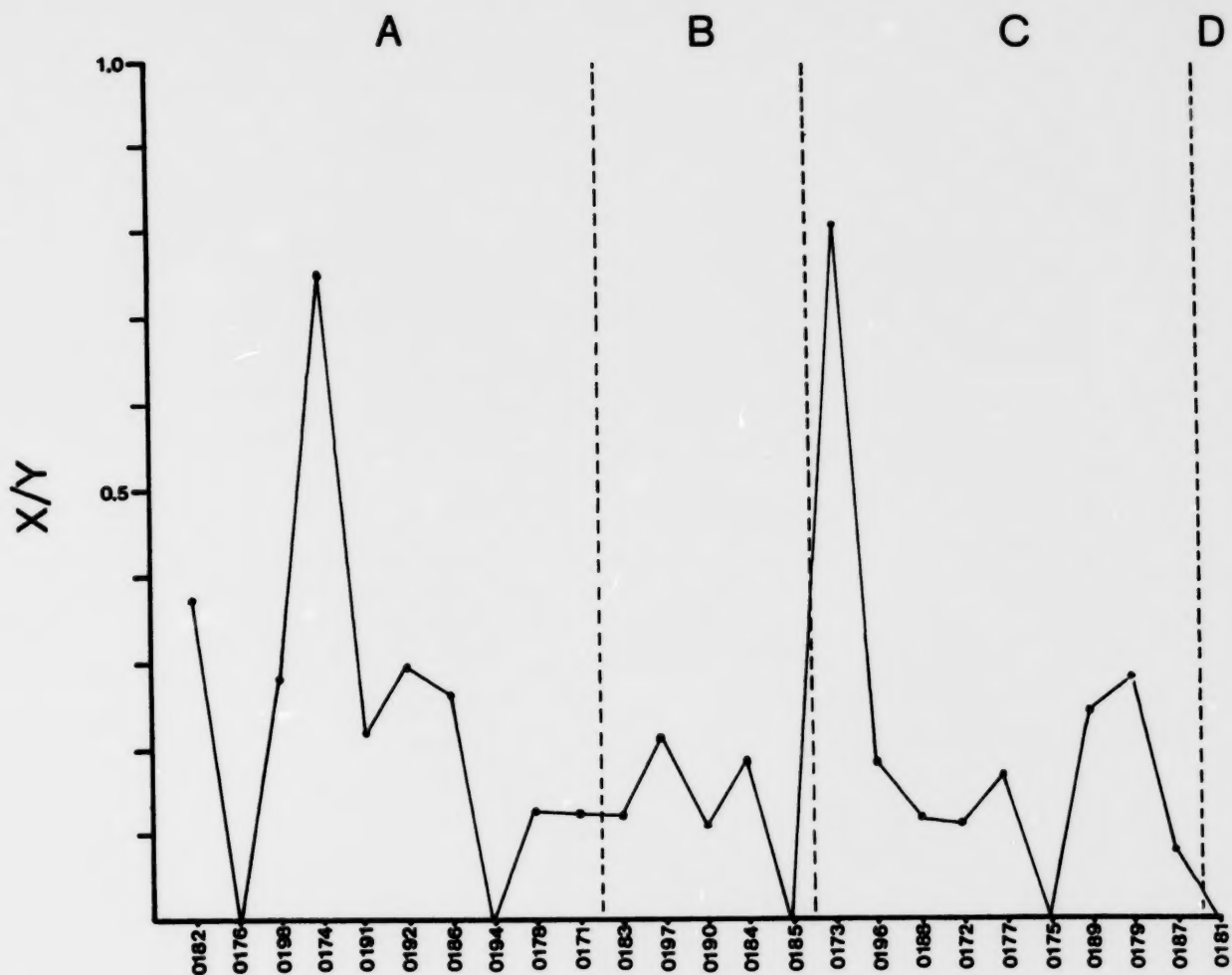


FIGURE 21. *AQUILAPOLLENITES* total vs fern total.

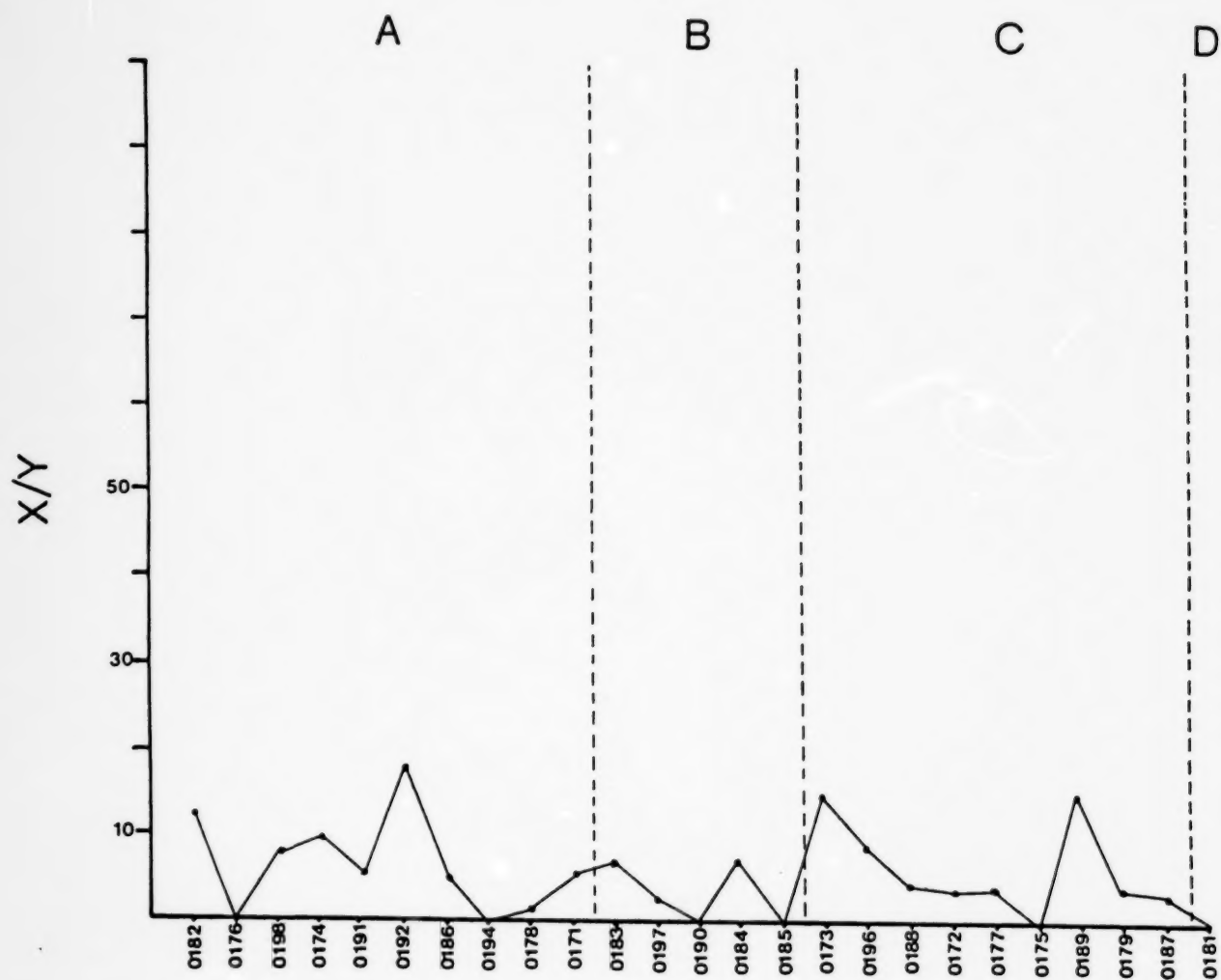


FIGURE 22. *AQUILAPOLLENITES total* vs *LAEVIGATOSPORITES OVATUS*.

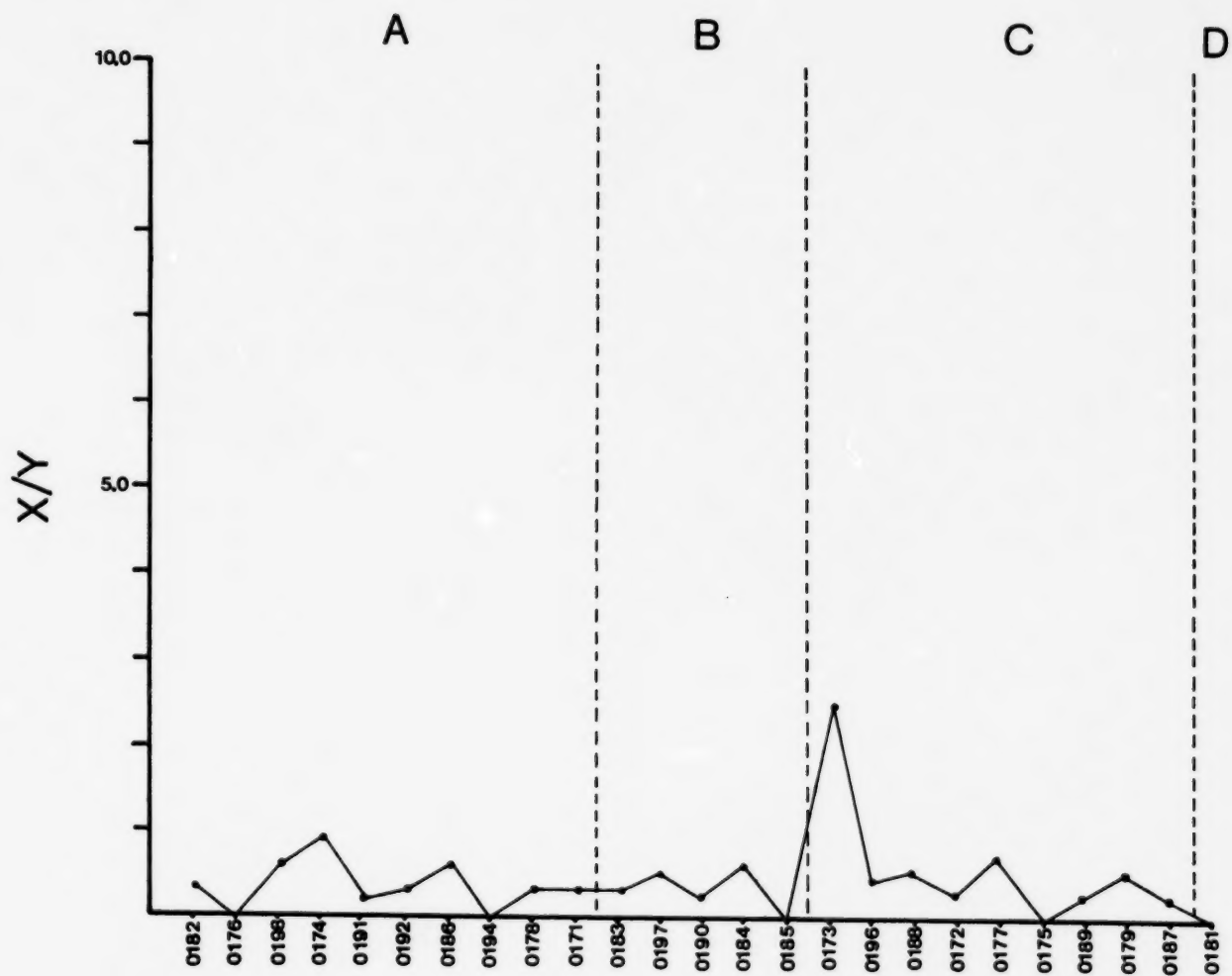


FIGURE 23. *AQUILAPOLLENITES* total vs gymnosperm total.

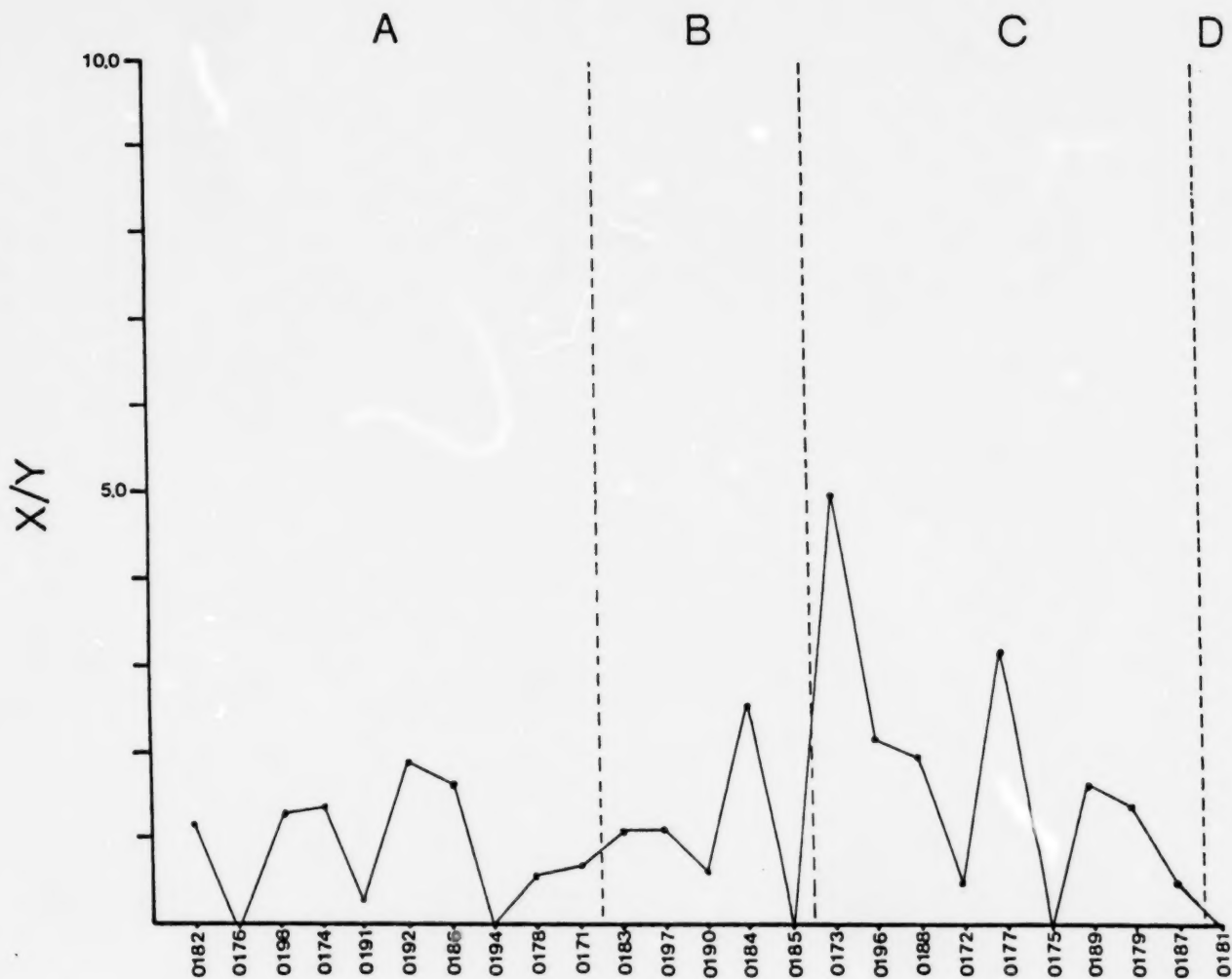


FIGURE 24. *AQUILAPOLLENITES* total vs *TAXODIACEAPOLLENITES* HIATUS.

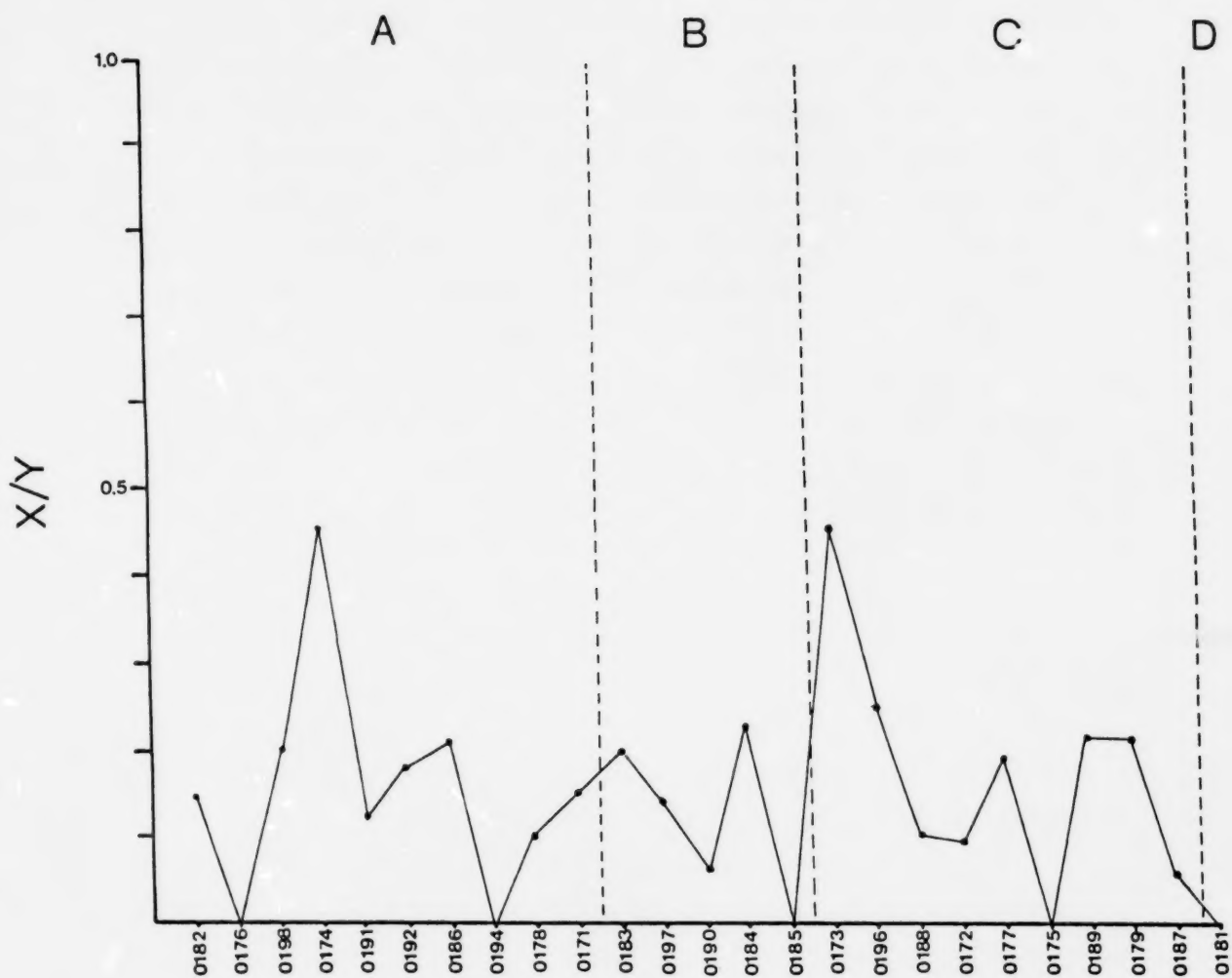


FIGURE 25. *AQUILAPOLLENITES* total vs angiosperm total.

M:t values for other areas were calculated for comparison, and strengthens the correlation between m:t values and geography. These include Chile m:t = 1.33 (Heusser, 1971), Argentina m:t = 0.92 (Margraf and D'Antoni, 1978), Colombia genera m:t = 0.87, species m:t = 0.68 (Murillo and Bless, 1974; 1978), New Zealand m:t = 0.97 (Harris, 1955).

The m:t values for Upper Cretaceous spore floras from several localities within the western interior were calculated as a measure of their environmental/geographical placement relative to present day values as quoted above. The following are representative: Hell Creek Montana m:t = 0.53 (Norton and Hall, 1969); Northwestern South Dakota m:t = 0.43 (Stanley, 1965); North Dakota m:t = 0.19 (Artzner, 1974); Strathmore Well, Southern Alberta m:t = 0.25 (Awai-Thorne, 1972); Dinosaur Provincial Park, Alberta, m:t = 0.63 (present study).

These data suggest that the environment during the time of deposition of these Upper Cretaceous sediments was similar to that of present day Colombia; a tropical wet lowland environment.

SUMMARY OF RESULTS

The preceeding pages of this paper have analyzed and described several individual aspects (viz. composition, abundance, botanical affinities and correlation) of the palynoflora recovered from 35 rock samples collected from Dinosaur Provincial Park, Alberta. The importance of these data are outlined below, with (when appropriate) suggestions for further investigations.

- (1) The flora from Dinosaur Provincial Park is diverse, and often within several samples, very abundant and beautifully preserved. This paper is the first attempt at describing and recording the flora which represents a sampling of the plant life which existed within a local geographically small region of southeastern Alberta approximately 75 million years ago.
- (2) Although all major plant groups (fern, bryophyte, gymnosperm, and angiosperm pollen) were recovered from the rock sediments, the angiosperms are best represented. The abundance of *Aquilapollenites* pollen suggests a large population of parasitic plants, perhaps perched high in the branches of large hardwood and softwood arboreal taxa (*Taxodiaceapollenites hiatus*)
- (3) The identified flora of 85 species is only an indication of the total vegetational cover

which must have existed at this time, inasmuch as the unidentified palynomorphs (recorded as C₁, C₃, C₃ P₃ etc. on Tables I and II) are often the most numerically abundant forms.

Continued, detailed analysis of these forms using both transmitted and scanning electron microscopy is needed to fully elucidate the botanical affinities of these palynomorphs.

(4) The Dinosaur Provincial Park flora correlates well with other late Upper Cretaceous floras, and especially so with the flora described by Arai-Thorne (1972). These correlations suggest that during the Campanian much of the North American western interior was dominated floristically with a similar, homogenous plant cover with minor local variation and speciation.

(5) Botanically, the flora represents a cross section of the vegetational cover, and includes mosses, hornworts, lycopods, ferns, cycads, conifers, and flowering plants. With extensive reference collections of recent pollen and spores, supplemented with adequate literature searches, several more affinities are to be expected to be elucidated. The process of "keying out" the botanical relationships is directly related to the extent of the reference collections and the time spent behind the microscope. Much additional work is needed in this regard.

(6) Several palynomorph groups are but briefly mentioned within this paper. These groups require specific expertise and often special techniques to insure their preservation and recovery. Further investigations could be carried out on the megaspore flora, the fungal and algal elements and the infrequent but present dinoflagellate flora.

(7) Additional numerical analyses and mathematical tests may reveal significant correlations and/or species groups prevalent across an east-west axis of the park. Preliminary inspection of the numerical data presented here, however do not indicate floristic regions, geographical or stratigraphical variation or correlate with the vertebrate data presented by Béland and Russell, 1978).

(8) This study must stand on its own as the preliminary analysis of the pollen and spore assemblages recovered from Dinosaur Provincial Park, and representing a cross-section of the vegetational cover which existed in this region 75 million years ago. A time of dinosaurs and tropical climate. A part of Canada's past now hidden, but gleaned ever so slowly from the rocks.

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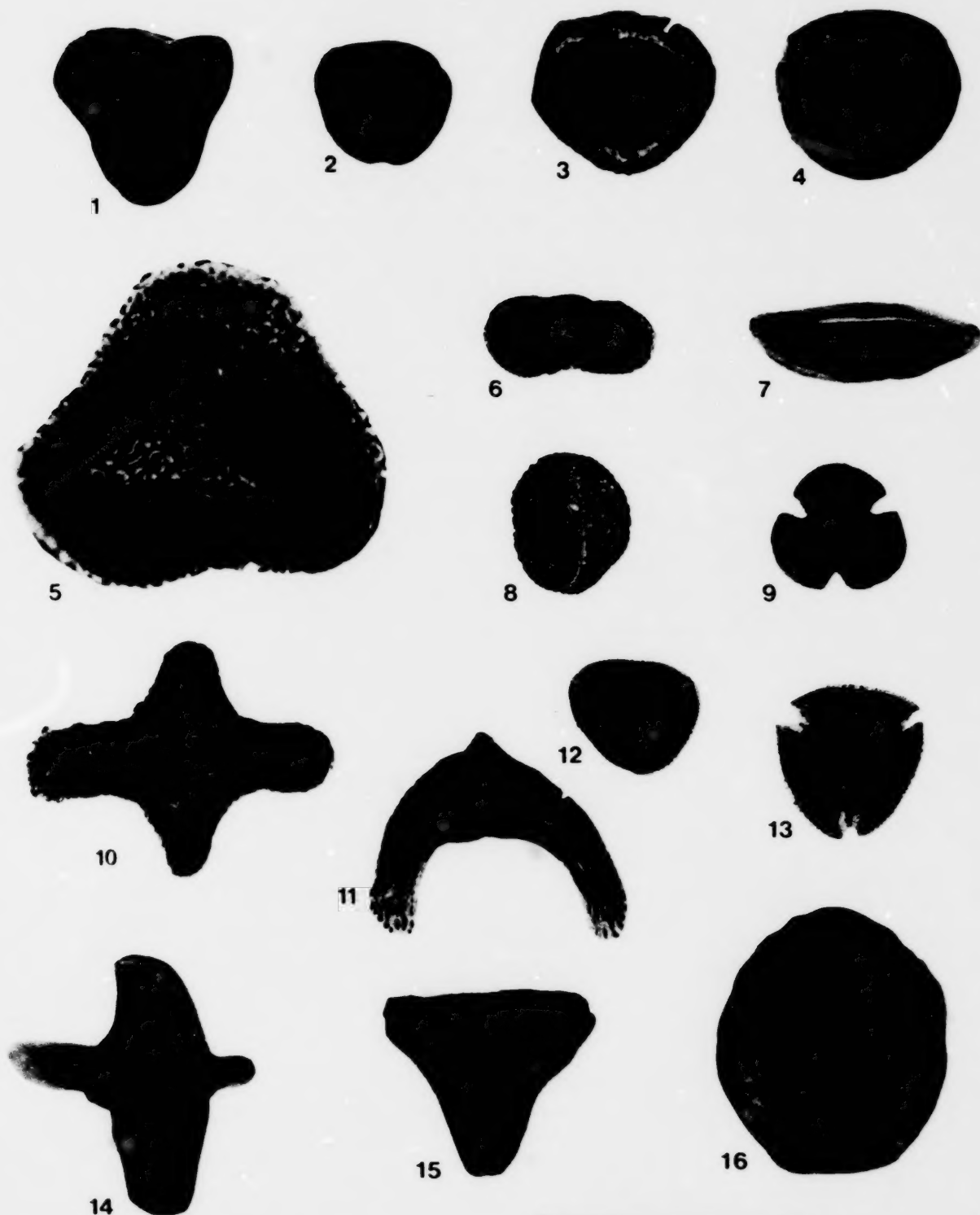
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PLATE DESCRIPTION

(length of bar = 50 μ m)

- FIGURE 1. *CYATHIDITES MINOR* Couper, 0183/1 A-1 >20 μ m, 92.4 $\times$ 32.6; ESF R33-1.
- FIGURE 2. *STEREISPORITES ANTIQUASPORITES* (Wilson and Webster) Dettman, 0191/1 A-1 >20 μ m, 85.6 $\times$ 34.4; ESF P26-1.
- FIGURE 3. *TAUROCUSPORITES REDUNCUS* (Bolkh.) Stover, 0183/1 A-1 >20 μ m, 83.1 $\times$ 36.2; ESF N23.
- FIGURE 4. *ZLIVISPORIS NOVAMEXICANUM* (Anderson) Leffingwell, 0183/1 A-1 >20 μ m, 86.9 $\times$ 36.0; ESF N27. Note faint trilete mark on proximal face.
- FIGURE 5. *TRILETES BETTIANUS* Srivastava, 0171/1 A-1 >20 μ m, 89.3 $\times$ 30.3; ESF T29-4.
- FIGURE 6. *VITREISPORITES PALLIDUS* (Reissinger) Nilsson, 0283/2 A-1 >20 μ m, 83.0 $\times$ 32.0; ESF R23.
- FIGURE 7. *EQUISETOSPORITES MULTICOSTATUS* (Brenner) Norris, 0191/1 A-2 >20 μ m, 96.0 $\times$ 38.7; ESF K36-4.
- FIGURE 8. *LILIACIDITES MORRINENSIS* Srivastava, 0184/1 A-1 >20 μ m, 86.2 $\times$ 35.3; ESF 026.
- FIGURE 9. *TRICOLPITES RETICULATUS* Cookson ex Couper, 0184/1 A-2 >20 μ m, 92.8 $\times$ 35.3; ESF 033.
- FIGURE 10. *AQUILAPOLLENITES ATTENUATUS* Funkhouser, 0184/1 A-1 >20 μ m, 88.7 $\times$ 42.6; ESF F29-3.
- FIGURE 11. *AQUILAPOLLENITES TRIPODIFORMIS* Tschudy and Leopold, 0183/1 A-1 >20 μ m, 91.3 $\times$ 27.8; ESF W31-2.
- FIGURE 12. *SENIPITES DRUMHELLERENSIS* Srivastava, 0171/1 A-5 >20 μ m, 90.3 $\times$ 37.0; ESF M30-4.
- FIGURE 13. *SYMPLOCOIPOLLENITES VESTIBULUM* (Potonié) Potonié, 0171/1 A-3 >20 μ m, 88.2 $\times$ 34.8; ESF 028-4.
- FIGURE 14. *AQUILAPOLLENITES TRIALATUS* Rouse, 0192/1 A-2 >20 μ m, 81.5 $\times$ 35.0; ESF 021-4.
- FIGURE 15. *TRUDOPOLLIS MEEKERI* Newman, 0189/1 A-2 >20 μ m, 83.8 $\times$ 42.1; ESF G24.
- FIGURE 16. *ERDTMANIPOLLIS PROCUMBENTIFORMIS* (Samoilovitch) Krutzsch, 0198/1 A-2 >20 μ m, 90.5 $\times$ 31.4; ESF S31-1.

CAMPANIAN PALYNOMORPHS



APPENDIX I

DINOSAUR PROVINCIAL PARK, ALBERTA (OLDMAN FORMATION, CAMPANIAN)

LITHOLOGIC DESCRIPTION OF TURTLE MATRIX SAMPLES

SAMPLE No.	DESCRIPTION
0181/1	Lsd. 13, Sect. 16, Twp. 21, R. 10 (Tier D): pale yellowish brown fine to medium grained sandstone with some yellowish gray clay balls and carbonaceous flecks. Matrix from <i>Baena</i> sp. turtle collected by C.M. Sternberg in 1921 (Field No.: CMS No. 13-1921) 4 miles below Happy Jack Ferry, 200' above river level.
0182/1	Lsd. 4, Sect. 29, Twp. 21, R. 12 (Tier A): pale yellowish brown fine to medium gray clay balls and carbonaceous flecks. Matrix from <i>Baena</i> sp. turtle collected by C.M. Sternberg in 1928 (Field No.: CMS No. 13-1928) about 3 miles southwest of Steveville, about 140' below the top of the formation.
0183/1	Lsd. 13, Sect. 35, Twp. 20, R. 12 (Tier B): pale yellowish brown fine to medium grained sandstone with some yellowish gray clay balls and carbonaceous flecks. Matrix from <i>Baena</i> sp. turtle collected by C.M. Sternberg in 1919 (Field No.: CMS No. 4-1919) on south side of west branch of Sand Creek about 75' below the Pierre Shales.
0184/1	Lsd. 7, Sect. 35, Twp. 20, R. 12 (Tier B): light olive gray mudstone with clay balls and some pale yellowish brown medium grained sand and light brown plant tissue. Matrix from <i>Boremys</i> sp. turtle found by G.E. Lindblad in 1919 (Field No.: CMS No. 14-1919) 2½ miles southwest of mouth of Little Sandhill Creek about 15' below the Pierre Shales contact.
0185/1	Lsd. 11, Sect. 7, Twp. 21, R. 11 (Tier B): mixed yellowish gray mudstone/pale yellowish brown fine grained sandstone conglomerate with brownish orange plant tissue and quartzite particles. Matrix from <i>Aspideretes</i> sp. turtle found by J. Skillen in 1919 (Field No.: 13-1919) opposite the mouth of Little Sandhill Creek about 150' above the river.
0186/1	Lsd. 8, Sect. 28, Twp. 21, R. 12 (Tier A): mixed yellowish gray to pale olive fine grained sandstone/mudstone conglomerate with carbonaceous

- flecks and brownish orange plant tissue. Matrix from *Aspideretes* sp. turtle collected by C.M. Sternberg in 1928 (Field No.: CMS No. 11-1928) 1½ miles south of Steveville about 100' below the top of the formation.
- 0187/1 Lsd. 2, Sect. 33, Twp. 20, R. 11 (Tier C): pale yellowish brown fine to medium grained sandstone with orangish brown plant tissues and lignitic streaks throughout. Matrix from *Aspideretes* sp. turtle collected by C.M. Sternberg in 1917 (Field No.: CMS No. 23-1917) about 3 miles southeast of mouth of Little Sandhill Creek.
- 0188/1 Lsd. 3, Sect. 5, Twp. 21, R. 11 (Tier C): yellowish gray fine grained sandstone with carbonaceous flecks. Matrix from unidentified turtle found by G.F. Sternberg in 1914 (Field No.: CHS No. 24-1914) near head of breaks southeast of mouth of Little Sandhill Creek.
- 0189/1 Lsd. 4, Sect. 9, Twp. 21, R. 11 (Tier C): yellowish gray mixed fine grained sandstone/mudstone conglomerate. Matrix from *Adocus* sp. turtle collected by C.M. Sternberg in 1921 (Field No.: CMS No. 19-1921) 1½ miles east of mouth of Little Sandhill Creek.
- 0190/1 Lsd. 14, Sect. 26, Twp. 21, R. 12 (Tier B): yellowish gray fine grained sandstone with carbonaceous flecks and some light brown plant tissue. Matrix from *Basilemys* sp. turtle found by H. Lowe in 1928 (Field No.: CMS No. 10-1928) 2 miles southeast of Steveville about 100' below the top of the Belly River beds.
- 0191/1 Lsd. 13, Sect. 16, Twp. 21, R. 12 (Tier A): moderate yellowish brown sandstone/clayball conglomerate with an associated 1 mm thick band of hard black coal. Matrix from *Boremys* sp. turtle (NMC 2235) collected by C.H. Sternberg in 1913 (Field No.: CHS No. 11-1913) 3½ miles south southwest of Steveville on west side of the Red Deer River.
- 0192/1 Lsd. 15, Sect. 28, Twp. 21, R. 12 (Tier A): mixed grayish orange fine to medium grained sandstone/yellowish gray mudstone conglomerate with carbonaceous flecks throughout. Matrix from baenid turtle found by H. Shearman in 1954 (Field No.: GEL No. 11-1954) on east side of Red Deer River 1 mile below the Steveville ferry.
- 0194/1 Lsd. 8, Sect. 21, Twp. 21, R. 12 (Tier A): very pale orange to pale

yellowish brown medium grained sandstone with some moderate yellowish brown clayballs and a 1 mm thick hard black coal seam (compressed between the carapace-plastron margins). Matrix from *Boremys pulchra* turtle (NMC 2281 plesiotype) collected by Levi Sternberg in 1913 (Field No.: CHS No. 7-1913) 3 miles below Steveville on west side of Red Deer River about 100' above the river. Turtle figured in L.M. Lambe, 1914. Trans. Roy. Soc. Canada (3), 8; p. 14.

- 0196/1 Lsd. 12, Sect. 5, Twp. 21, R. 12 (Tier C): light gray to light olive gray fine grained sandstone with carbonaceous flecks throughout. Matrix from baenid turtle collected by C.M. Sternberg in 1917 (Field No.: CMS No. 19-1917) 1 mile southeast of mouth of Little Sandhill Creek.
- 0197/1 Lsd. 12, Sect. 26, Twp. 20, R. 12 (Tier B): dark to moderate yellowish brown clayball conglomerate with carbonaceous flecks throughout and some light olive gray clay balls. Matrix from *Aspideretes* sp. turtle found by G.E. Lindblad in 1917 (Field No.: CMS No. 19-1917) 3½ miles southwest of mouth of Sand Creek (Little Sandhill Creek).
- 0198/1 Lsd. 10, Sect. 29, Twp. 21, R. 12 (Tier A): yellowish gray fine grained sandstone with some grayish orange clay and an associated 1 mm thick band of hard black coal. Matrix from *Aspideretes* sp. turtle collected by G.E. Lindblad in 1954 (Field No.: GEL No. 5-1954) approximately 100' south of Quarry No. 61-13 (Quarry No. 16 on 1950 GSC map), i.e. 2 miles southwest of Steveville.

APPENDIX II

DINOSAUR PROVINCIAL PARK, ALBERTA (OLDMAN FORMATION, CAMPANIAN)

LITHOLOGIC DESCRIPTION OF OUTCROP SEDIMENT SAMPLES

SAMPLE No.	DESCRIPTION
0171/1	Lsd. 1, Sect. 34, Twp. 21, R. 12 (Tier A): moderate yellowish brown mudstone with some fine grained sand and plant tissue. Outcrop sediment sample collected by D.A. Russell (NMC) in 1980 from the Giant Pterosaur locality (specimen PMA P80.16.1367). At 2225' contour level.
0172/1	Lsd. 10, Sect. 32, Twp. 20, R. 11 (Tier C): light olive gray fine grained sandstone with a black organic layer and amber flecks. Outcrop sediment sample collected by D.A. Russell (NMC) in 1980 from a <i>Styracosaurus</i> bone bed 0.16 km north 5° west of Quarry No. 79 (refer to 1950 GSC map) at the same level.
0173/1	Lsd. 12, Sect. 32, Twp. 20, R. 11 (Tier C): grayish orange mudstone with black to orangish plant material. Outcrop sediment sample collected by D.A. Russell (NMC) in 1980 from a <i>Monoclonius</i> bone bed 91.5 m west of Quarry No. 77 (refer to 1950 GSC map) at about the same level.
0174/1	Lsd. 5, Sect. 28, Twp. 21, R. 12 (Tier A): moderate yellowish brown mudstone with some laminated yellowish gray fine grained sand and carbonaceous flecks throughout. Outcrop sediment sample collected by D.A. Russell (NMC) in 1980 near a hadrosaur tibia 7 m east of Quarry No. 21 (identified on field stake as fossil locality No. 20, UT 19).
0175/1	Lsd. 8, Sect. 5, Twp. 21, R. 11 (Tier C): moderate yellowish brown fine grained sandstone. Outcrop sediment sample collected by D.A. Russell (NMC) in 1980 from a <i>Centrosaurus</i> bone bed (Provincial Museum of Alberta bone bed) 91.5 m south of Quarry No. 88 at the same level.
0176/1	Lsd. 15, Sect. 8, Twp. 21, R. 12 (Tier A): grayish orange fine grained sandstone. Outcrop sediment sample collected by D.A. Russell (NMC) in 1980 at prairie level (2300' contour level, base of Bearpaw Formation) south of Onetree Creek. Associated with a concretion containing <i>Baculites</i> sp.

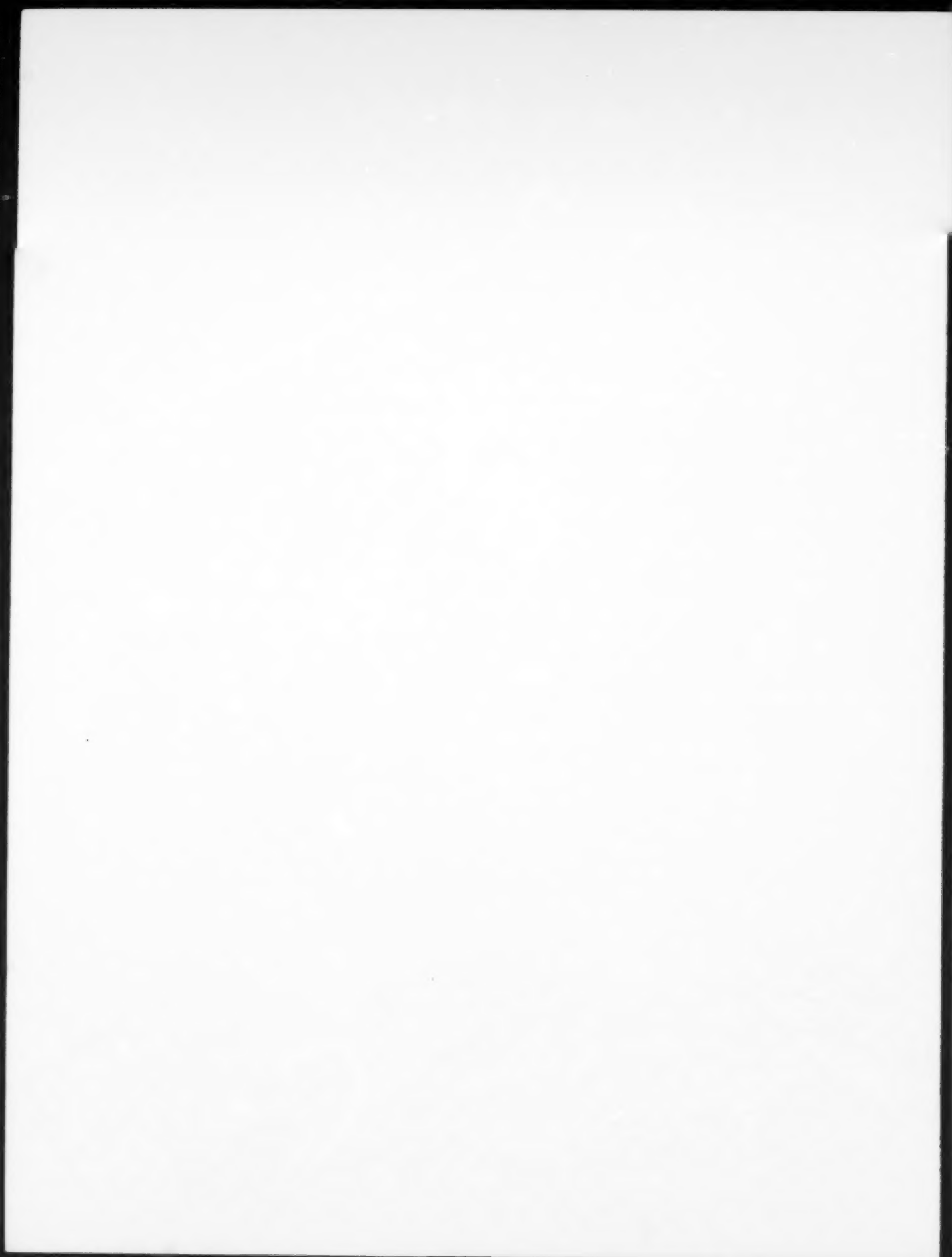
- 0177/1 Lsd. 11, Sect. 32, Twp. 20, R. 11 (Tier C): mixed light olive gray fine grained sandstone/yellowish gray to pale olive mudstone with carbonaceous flecks throughout. Outcrop sediment sample collected by D.A. Russell (NMC) in 1980 from a hadrosaur bone bed. At 2250' contour level.
- 0178 Lsd. 11, Sect. 27, Twp. 21, R. 12 (Tier A): outcrop sediment samples collected by D.A. Russell (NMC) in 1980 from upper part of Oldman Formation.
- 0178/1 Sediment sample collected from outcrop at the base of the section; dark yellowish brown friable mudstone.
- 0178/2 Sediment sample collected from outcrop, 839 cm upslope of previous sample; dusky yellowish brown lignite with plant tissue and amber flecks.
- 0178/3 Sediment sample collected from outcrop, 730 cm upslope of previous sample; laminated moderate yellowish brown fine grained sandstone/dark yellowish brown mudstone.
- 0178/4 Sediment sample collected from outcrop, 453 cm upslope of previous sample; dusky brown lignite with plant tissue and some yellowish gray medium grained sand.
- 0178/5 Sediment sample collected from outcrop, 134 cm upslope of previous sample; dark yellowish brown lignite.
- 0178/6 Sediment sample collected from outcrop, 201 cm upslope of previous sample; light brown fine to medium grained sandstone with some streaks of dark brown lignite. This sample was found 168 cm below prairie level (2300' contour level).
- 0179 Lsd. 12, Sect. 33, Twp. 20, R. 11 (Tier C): outcrop sediment samples collected by D.A. Russell (NMC) in 1980 at the major westwardly projecting point in the north-south escarpment.
- 0179/1 Sediment sample collected from outcrop at the base of the section; mixed yellowish gray fine grained sandstone/mudstone ("bentonitic shale").
- 0179/2 Sediment sample collected from outcrop, 670 cm upslope of previous sample; mixed pale yellowish brown fine grained sandstone/dark yellowish brown mudstone.
- 0179/3 Sediment sample collected from outcrop, 503 cm upslope of previous sample;

dark yellowish brown mudstone with some fine grained sand and
carbonaceous flecks.

0179/4 Sediment sample collected from outcrop, 335 cm upslope of previous sample;
dark yellowish brown mudstone.

0179/5 Sediment sample collected from outcrop, 335 cm upslope of previous sample;
pale yellowish brown mudstone.

0179/6 Sediment sample collected from outcrop, 335 cm upslope of previous sample;
yellowish gray to grayish yellow green fine grained laminar sandstone.
This sample was found 419 cm below prairie level (2425' contour level).



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